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CHEMICAL ESSAYS.

BY

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G.R. III
BR MUS

TO

HIS GRACE

THE

DUKE OF RUTLAND.

MY LORD DUKE,

YOUR GRACE, whilſt I had the honour of being intruſted with your Education in this place, ſhewed a diſpoſition to the Study of Chemiſtry: I wiſh that any thing contained in the following Eſſays may tend to revive it.

Chemiſtry is cultivated abroad by perſons of the firſt Rank, Fortune, and Ability; they find in it a never failing ſource of honourable amuſement for their private hours; and as public men, they conſider its cultivation as one of the moſt certain means of bringing to their utmoſt perfection, the manufactures of their country.

That your GRACE'S private life may continue to be bleſſed with every domeſtic comfort; and that your public life may be diſtinguiſhed by principles and actions uſeful to your country, and honourable to yourſelf, is the ſincere prayer of

Your GRACE'S

Moſt affectionate

And obliged Servant,

Cambridge,
Feb. 20, 1781.

R. WATSON.

PREFACE.

THE ſubjects of the following Eſſays have been choſen, not ſo much with a view of giving a Syſtem of Chemiſtry to the world, as with the humbler deſign of conveying, in a popular way, a general kind of knowledge, to perſons not much verſed in chemical inquiries.

Two other volumes, which are nearly ready for the preſs, would finiſh the whole of my plan; but being quite doubtful how far either the ſubject itſelf, or at leaſt, how far the manner in which I have been able to treat it, may be acceptable to the Public, I dare not at preſent venture to ſolicit the Reader's attention to them: if they ſhould never ſee the light, the world will ſuffer little loſs; and as to the trouble and expence which I have been at in compoſing them, they are more than compenſated by the knowledge I have gained.

There are two ſets of men of whom I particularly crave indulgence — Chemiſts, and Divines. Chemiſts muſt excuſe me, as well for having explained common matters, with what will appear to them a diſguſting minuteneſs, as for having paſſed over in ſilence ſome of the moſt intereſting queſtions: ſuch are thoſe which reſpect the analyſis of air and fire, the production and tranſmutation of ſaline ſubſtances, the ſpontaneous deſtruction and generation of minerals.

PREFACE.

Divines, I hope will forgive me, if I have ſtolen a few hours, not, I truſt, from the duties of my office, but certainly from the ſtudies of my profeſſion, and employed them in the cultivation of natural philoſophy: I could plead in my defence the example of ſome of the greateſt characters, that ever adorned either this Univerſity or the Church of England. The books of Nature and of Revelation equally elevate our conceptions, and incite our piety; they mutually illuſtrate each other; they have an equal claim to our regard, for they are both written by the finger of the ONE ETERNAL INCOMPREHENSIBLE GOD, TO WHOM BE GLORY FOR EVER, AMEN.

For the miſtakes I may have fallen into in treating of ſuch a variety of matter, and for the imperfection in the deſign and execution of the Work itſelf, I generally intreat the Reader's excuſe in the words of Pliny,

> *Occupati ſumus officiis, ſubſeciviſque horis iſta curamus.*

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ESSAY

ESSAY I.

On the Riſe and Progreſs of Chemiſtry.

THE beginnings of every art, which tended either to ſupply the neceſſities, or to alleviate the more preſſing inconveniences of human life, were probably coeval with the firſt eſtabliſhment of civil ſocieties, and preceded by many ages, the invention of letters, of hieroglyphics, and of every other mode of tranſmitting to poſterity the memory of paſt tranſactions. In vain ſhall we inquire who invented the firſt plough, baked the firſt bread, ſhaped the firſt pot, wove the firſt garment, or hollowed out the firſt canoe. Whether men were originally left, as they are at preſent, to pick up caſual information concerning the properties of bodies, and to inveſtigate by the ſtrength of natural genius the various relations of the objects ſurrounding them; or were, in the very infancy of the world, ſupernaturally aſſiſted in the diſcovery of matters eſſential, as it ſhould ſeem, to their exiſtence and well-being, muſt ever remain unknown to us.

There can be little doubt that in the ſpace of, at leaſt, 1656 years, from the creation of the world to the deluge, a great variety of economical arts muſt have been carried to a very conſiderable degree of perfection. The knowledge of many of theſe periſhed,

riſhed, in all likelihood, with the then inhabitants of the earth; it being ſcarcely poſſible for that ſingle family which eſcaped the general ruin to have either practiſed, or been even ſuperficially acquainted with them all. When men have been long united in civil ſocieties, and human nature has been exalted by a reciprocal communication of knowledge, it does not often happen, that any uſeful invention is intirely loſt: but were all the preſent inhabitants of the earth, except eight perſons, to be deſtroyed by one ſudden calamity, who ſees not that moſt of thoſe ſerviceable and elegant arts, which at preſent conſtitute the employment, and contribute to the happineſs of the greateſt part of the human race, would probably be buried in long oblivion? Many centuries might ſlip away, before the new inhabitants of the globe would again become acquainted with the nature of the compaſs, with the arts of painting, printing, or dying, of making porcelane, gun-powder, ſteel, or braſs.

The interval of time which elapſed from the beginning of the world to the firſt deluge, is reckoned by profane hiſtorians, to be wholly uncertain as to the events which happened in it: it was antecedent, by many centuries, not only to the æra when they ſuppoſed hiſtory to commence, but to the moſt diſtant ages of heroiſm and fable. The only account relative to it, which we can rely upon, is contained in the firſt ſix chapters of the book of Geneſis; three of which being employed in the hiſtory of the creation, and of the fall of man; and a fourth containing nothing but a genealogical narration of the patriarchs from Adam to Noah; it cannot reaſonably be expected, that the other two ſhould enable us to trace the various ſteps by which the human intellect advanced in the cultivation of arts and ſciences, or to aſcertain, with much preciſion, the time when any of them was firſt introduced into the world. It is ſomewhat remarkable that from this account, ſhort as it is, the chemiſts ſhould be authorized, with ſome propriety, to exalt the antiquity of their art to the earlieſt times. Tubal-cain is there mentioned as an inſtructor of every artificer in copper and iron *. This circumſtance proves beyond diſpute, that one

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* Gen. iv. 22.

one part of metallurgic chemiſtry was well underſtood at that time, for copper and iron are of all the metals moſt difficultly extracted from their ores, and cannot, even in our days, be rendered malleable without much ſkill and trouble; and it proves alſo that the arts in general were in an improved ſtate amongſt the antediluvians. It is ſaid, indeed, that ſome tribes of Hottentots (who can have no pretenſions to be ranked amongſt the cultivators of the arts) know how to melt both iron and copper†; but this knowledge of theirs, if they have not derived it from an intercourſe with the Europeans, is a very extraordinary circumſtance, ſince the melting and manufacturing of metals are juſtly conſidered, in general,

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† Forſter's Voy. Vol. I. p. 81.

neral, as indications of a more advanced ſtate of civilization than the Hottentots have yet arrived at. But not to dwell upon this; Cain we know built a city, and ſome would thence infer that metals were in uſe before the time of Tubal-cain, and that he is celebrated principally for his ingenuity in fabricating them for domeſtic purpoſes. Hiſtory ſeems to ſupport our pretenſions thus far. As to the opinion of thoſe who, too zealouſly contending for the dignity of chemiſtry, make the diſcovery of its myſteries to have been the *pretium amoris* which angels paid to the fair daughters of men, we in this age are more diſpoſed to apologize for it than to adopt it. We may ſay of arts what the Roman hiſtorian has ſaid of ſtates—*datur* *hæc venia antiquitati*, *ut*, *miſcendo humana divinis*, *primordia* artium *auguſtiora faciat* §.

For many ages after the flood we have no certain accounts of the ſtate of chemiſtry. The art of making wine indeed, was known, if not before, ſoon after the deluge; this may be collected from the intoxication of Noah ||, there being no inebriating quality in the unfermented juice of the grape. The Egyptians were ſkilled in the manufacturing of metals, in medicinal chemiſtry, and in the art of embalming dead bodies, long before the time of Moſes, as appears from the mention made of Joſeph's cup *, and from the phyſicians being ordered to embalm the body of Jacob †. They practiſed

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§ Livy's Præf. || Gen. ix. 21.
* Gen. xliv. 2. † Gen. l. 2.

alſo the arts of dying and of making coloured glaſs at a very early period; as has been gathered, not only from the teſtimony of Strabo, but from the relics found with their mummies, and from the glaſs beads with which their mummies are ſometimes ſtudded §. But we cannot from theſe inſtances conclude that chemiſtry was then cultivated as a ſeparate branch of ſcience, or diſtinguiſhed in its application, from a variety of other arts which muſt have been exerciſed for the ſupport and convenience of human life. All of theſe had probably ſome dependance on chemical principles, but they were then, as they are at preſent, practiſed by the ſeveral artiſts without their having any theoretical knowledge of their reſpective employments. Nor can we pay much attention in this inquiry to the obſcure accounts which are given of the two great Egyptian philoſophers, Hermes the elder, ſuppoſed to be the ſame with Mizraim grandſon of Noah; and Hermes ſurnamed Triſmegiſtus the younger, from whom chemiſtry has by ſome been affectedly called the Hermetic art.

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§ See Delaval's ingenious Inquiry into the Cauſe of the Changes of Colours, Pref. LVI: and Dutens's learned Inquiry into the Diſcoveries attributed to the Moderns, p. 241.

The chemical ſkill of Moſes, diſplayed in his burning, reducing to an impalpable powder, and rendering potable the golden calf in the wilderneſs, has been generally extolled by writers on this ſubject; and conſtantly adduced as a proof of the then flouriſhing ſtate of chemiſtry amongſt the Egyptians, in whoſe learning he is ſaid to have been well verſed. If Moſes had really reduced the gold of which the calf conſiſted, into aſhes, by calcining it in the fire; or made it any other way ſoluble in water, this inſtance would have been greatly in point; but neither in Exodus nor in Deuteronomy where the fact is mentioned, is there any thing ſaid of its being diſſolved in water. The enemies of revelation on the other hand, conceiving it to be impoſſible to calcine gold, or to render it potable, have produced this account as containing a proof of the want of veracity in the ſacred hiſtorian. Both ſides ſeem to be in an error; Stahl and other chemiſts have ſhewn that it is poſſible to make gold potable, but we have no reaſon to conclude that Moſes either uſed the proceſs of Stahl, or any other chemical means for effecting the purpoſe intended—*he took the calf which they had made, and burnt it in the fire, and ground it to powder, and ſtrewed it upon the water, and made the children of Iſrael to drink of it*[*]. Here is not the leaſt intimation given of the gold having been diſſolved, chemically ſpeaking, in water; it was ſtamped and ground, or, as the Arabic and Syriac verſions have it, filed into a fine duſt, and thrown into the river of which the children of Iſrael uſed to drink: part of the gold would remain, notwithſtanding its greater ſpecific gravity, ſuſpended for a time, (as happens in the waſhing of copper

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[*] Exod. xxxii. 20.

per and lead ores,) and might be ſwallowed in drinking the water, the reſt would ſink to the bottom, or be carried away by the flux of the ſtream.

Nevertheleſs, though nothing ſatisfactory can be concluded concerning the Egyptian chemiſtry from what is ſaid of Moſes in this inſtance, yet the ſtructure of the ark, and the faſhion of Aaron's garments, clearly indicate to us that the arts of manufacturing metals, of dying leather red and linen blue, purple, and ſcarlet; of diſtinguiſhing precious ſtones, and engraving upon them, were at that time practiſed in a very eminent degree *. The Iſraelites had unqueſtionably learned theſe arts in Egypt, and there is great reaſon

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* Exod. xxvi. and xxviiii.

ſon to ſuppoſe not only that learning of every kind firſt flouriſhed in Egypt, but that chemiſtry, in particular, was much cultivated in that country when other ſciences had paſſed into other parts of the world. Pliny in ſpeaking of the four periods of learning which had preceded the times in which he lived, reckons the Egyptian the firſt: and Suidas, who is thought to have lived in the tenth century, informs us that the Emperor Diocletian ordered all the books of chemiſtry to be burned, leſt the Egyptians learning from them the art of preparing gold and ſilver, ſhould thence derive reſources to oppoſe the Romans *. It is worthy of notice that Suidas uſes the word chemiſtry in a very reſtricted ſenſe, when

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* Lexicon, Vox Χημεια.

when he interprets it by—the preparation of gold and ſilver;—but all the chemiſts in the time of Suidas, and for many ages before and after him, were alchemiſts. The edict of Diocletian in the third century, had little effect in repreſſing the ardour for this ſtudy in any part of the world, ſince we are told that not leſs than five thouſand books, to ſay nothing of manuſcripts, have been publiſhed upon the ſubject of alchemy ſince his time *.

At what particular period this branch of chemiſtry, reſpecting the tranſmutation of the baſer metals into gold, began to be diſtinguiſhed by the name of alchemy, cannot be determined. An author of the fourth century, in an aſtrological work,

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* Chem. Waller, p. 40.

work, ſpeaks of the ſcience of alchemy as well underſtood at that time; and this is ſaid to be the firſt place in which the word alchemy is uſed*. But Voſſius aſſerts that we ought in the place here referred to inſtead of *alchemia* to read *chemia* †: be this as it may, we can have no doubt of *alchemia* being compounded of the Arabic *al* (the) and *chemia*, to denote excellence and ſuperiority, as in al-manack, al-koran, and other words. Whether the Greeks invented, or received from the Egyptians, the doctrine concerning the tranſmutation of metals, or whether the Arabians were the firſt who profeſſed it, is uncertain. To change iron, lead, tin, copper, quickſilver into gold, ſeems to be a problem more likely to animate mankind to attempt its ſolution, than either that of ſquaring the circle, or of finding out a perpetual motion; and as it has never yet been proved, perhaps never can be proved to be an *impoſſible problem*, it ought not to be eſteemed a matter of wonder, that the firſt chemical books we meet with, are almoſt intirely employed in alchemical inquiries.

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* Jul. Fermi. Mater. Aſtronomicon. Lib. 3. c. 15.

† Voſs. Etymo. Vox Alchemia.

Chemiſtry, with the reſt of the ſciences, being baniſhed from the other parts of the world, took refuge among the Arabians. Geber in the ſeventh, or as ſome will have it in the eighth, and others in the ninth century, wrote ſeveral chemical or rather alchemical books in

Arabic. In theſe works of Geber are contained ſuch uſeful directions concerning the manner of conducting diſtillation, calcination, ſublimation, and other chemical operations, and ſuch pertinent obſervations reſpecting various minerals, as juſtly ſeem to entitle him to the character, which ſome have given him, of being the father of chemiſtry; though, in one of the moſt celebrated of his works, he modeſtly acknowledges himſelf to have done little elſe than abridge the doctrine of the ancients concerning the tranſmutation of metals*. Whether he was preceded by Meſuè and Rhazès, or followed by them, is not in the preſent inquiry a matter of much importance to determine, ſince the forementioned phyſicians as well as Avicenna, who, from all accounts, was poſterior to Geber, ſpeak of many chemical preparations, and thus thoroughly eſtabliſh the opinion, that medical chemiſtry, as well as alchemy, was in thoſe dark ages well underſtood by the Arabians.

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* Totam noſtram metallorum tranſmutandorum ſcientiam, quam ex libris antiquorum philoſophorum abbreviavimus, compilatione diverſa, in noſtris voluminibus, hic in unam ſummam redegimus. Gebri Alch. cap. 1. edition by Zetzner in 1512. In Tancken's edition in 1681, the words metallorum tranſmutandorum are omitted.

Towards the beginning of the thirteenth century Albert the Great in Germany, and Roger Bacon in England, began to cultivate chemiſtry with ſucceſs, excited thereto, probably, by the peruſal of ſome Arabic books, which about that time were tranſlated into Latin. Theſe two monks, eſpecially the latter, ſeem to have as far exceeded the common ſtandard of learning in the age in which they lived, as any philoſophers who have appeared in any country either before their time or ſince. They were ſucceeded in the fourteenth and fifteenth centuries, by a great many eminent men both of our own country and foreigners, who, in applying themſelves to alchemy, made, incidentally, many uſeful diſcoveries in various parts of chemiſtry: ſuch were Arnoldus de Villa Nova in France; our countryman George Ripley; Raymund Lully of Majorca, who firſt introduced or at leaſt more largely explained the notion of an univerſal medicine; and Baſile Valentine, whoſe excellent book intitled *Currus Antimonii triumphalis*, has contributed more than any thing elſe to the introduction of that moſt uſeful mineral into the regular practice of moſt phyſicians in Europe; it has given occaſion alſo to a variety of beneficial, as well as (a circumſtance which might be expected, when ſo tickliſh a mineral fell into the hands of intereſted empirics) to many pernicious *noſtrums*. To this, rather than to the arrogant ſeverity with which Baſile Valentine treats the phyſicians his cotemporaries, may we attribute the cenſure of Boerhaave, who, in ſpeaking of him, ſays, " he erred chiefly in this, that he commended every antimonial preparation, than which nothing can be more fooliſh, fallacious, and dangerous; but this fatal error has infected every medical ſchool from that time to this [†].

[†] Boerh. Ch. Vol. I. p. 18.

The attempting to make gold or ſilver by alchemical proceſſes had been prohibited by a conſtitution of Pope John the XXII, who was elevated to the pontificate in the year 1316*; and within about one hundred and twenty years from the death of friar Bacon, the nobility and gentry of England had become ſo infatuated with the notions of alchemy, and waſted ſo much of their ſubſtance in ſearch of the philoſopher's ſtone, as to render the interpoſition of government neceſſary to reſtrain their folly. The following act of parliament, which lord Coke calls the ſhorteſt he ever met with, was paſſed 5 H. 4. "None from henceforth ſhall uſe to multiply gold or ſilver, or uſe the craft of multiplication,

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* Kirch. Mun. Sub. L. xi. Sect. iv. c. i.

tion, and if any the ſame do, he ſhall incur the pain of felony." It has been ſuggeſted, that the reaſon of paſſing this act was not an apprehenſion leſt men ſhould ruin their fortunes by endeavouring to make gold, but a jealouſy leſt government ſhould be above aſking aid of the ſubject. "After Raymund Lully, and Sir George Ripley, had ſo largely multiplied gold, the lords and commons, conceiving ſome danger that the regency, having ſuch immenſe treaſure at command, would be above aſking aid of the ſubject, and might become too arbitrary and tyrannical, made an act againſt multiplying gold and ſilver †." This act, whatever might be the occaſion of paſſing it, though it gave ſome ob-

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† Opera Mineralia explicata, p. 10.

obſtruction to the public exerciſe of alchemy, yet it did not cure the diſpoſition for it in individuals, nor remove the general credulity; for in the 35 H. 6. Letters Patent were granted to ſeveral people, by which they were permitted to inveſtigate an univerſal medicine, and to perform the tranſmutation of metals into real gold and ſilver, with a non-obſtante of the forementioned ſtatute, which remained in full force till the year 1689, when being conceived to operate to the diſcouragement of the melting and refining of metals, it was formally repealed *. The

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* Mr. Boyle is ſaid by his intereſt to have procured the repeal of this ſingular ſtatute, and to have been probably induced thereto, in conſequence of his having been perſuaded of the poſſibility of the tranſmutation of metals into gold. See his Life prefixed to the folio ed. of his works, p. 83.

The beginning of the ſixteenth century was remarkable for a great revolution produced in the European practice of phyſic, by means of chemiſtry. Then it was that Paracelſus, following the ſteps of Baſile Valentine, and growing famous for curing the venereal diſeaſe, the leproſy, and other virulent diſorders, principally by the means of mercurial and antimonial preparations, wholly rejected the Galenical pharmacy, and ſubſtituted in its ſtead the chemical. He had a profeſſor's chair given him by the magiſtracy of Baſil, was the firſt who read public lectures in medicine and chemiſtry, and ſubjected animal and vegetable as well as mineral ſubſtances to an examination by fire.

It ſeldom happens that a man of but common abilities, and in the moſt retired ſcenes of life, obſerves ſuch a ſtrict uniformity of conduct, as not to afford prejudice and partiality ſufficient materials for drawing his character in different colours; but ſuch a great and irregular genius as Paracelſus, could not fail of becoming alike, the ſubject of the extremes of panegyrick and ſatire. He has accordingly been eſteemed by ſome, a ſecond Eſculapius; others have thought that he was poſſeſſed of more impudence than merit, and that his reputation was more owing to the brutal ſingularity of his conduct, than to the cures he performed. He treated the phyſicians of his time, with the moſt ſottiſh vanity and illiberal inſolence; telling them, that the very down of his bald pate had more knowledge than all their writers,

ters, the buckles of his ſhoes more learning than Galen or Avicenna, and his beard more experience than all their univerſities *. He revived the extravagant doctrine of Raymund Lully, concerning an univerſal medicine, and untimely ſunk into his grave at the age of forty-ſeven, whilſt he boaſted himſelf to be in poſſeſſion of ſecrets able to prolong the preſent period of human life to that of the Antediluvians.

But in whatever eſtimation the merit of Paracelſus as a chemiſt may be held, certain it is, that his fame excited the envy of ſome, the emulation of others, and the induſtry of all. Thoſe who attacked, and thoſe who defended his principles, equally promoted

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* Preface to his book entitled Paragranum, where there is more in the ſame ſtile.

promoted the knowledge of chemiſtry; which from his time, by attracting the notice of phyſicians, began every where to be ſyſtematically treated, and more generally underſtood.

Soon after the death of Paracelſus, which happened in the year 1541, the arts of mining and fluxing metals, which had been practiſed in moſt countries from the earlieſt times, but had never been explained by any writers in a ſcientific manner, received great illuſtration from the works of Georgius Agricola, a German phyſician. The Greeks and Romans had left no treatiſes worth mentioning upon the ſubject, and though a book or two had appeared in the German language, and one in the Italian, relative to metallurgy, before Agricola publiſhed his twelve books *De Re Metallica*, yet he is juſtly eſteemed the firſt author of reputation in that branch of chemiſtry.

Lazarus Erckern (aſſay-maſter general of the empire of Germany) followed Agricola in the ſame purſuit. His works were firſt publiſhed at Prague in 1574, and an Engliſh tranſlation of them by Sir John Pettus, came out at London in 1683. The works of Agricola and Erckern are ſtill highly eſteemed, though ſeveral others have been publiſhed, chiefly in Germany, upon the ſame ſubject ſince their time. Amongſt theſe we may reckon Schindler's Art of Aſſaying Ores and Metals; the metallurgic works of Orſchall; the works of Henckell; of Sclutter; of Cramer; of Lehman;

and of Gellert. Germany, indeed, has for a long time been the great ſchool of metallurgy for the reſt of Europe; and we, in this country, owe the preſent flouriſhing condition of our mines, eſpecially of our copper mines, as well as of our braſs manufactory, to the wiſe policy of queen Elizabeth, in granting great privileges to Daniel Houghſetter, Chriſtopher Schutz, and other Germans, whom ſhe had invited into England, in order to inſtruct her ſubjects in the art of metallurgy.

It was not, however, till towards the middle of the laſt century, that general chemiſtry began to be cultivated in a liberal and philoſophical manner. So early as the year 1645 ſeveral ingenious perſons in London, in order to divert their thoughts from the horrors of the civil war which had then broken out, had formed themſelves into a ſociety, and held weekly meetings, in which they treated of, what was then called, the new or experimental philoſophy. Theſe meetings were continued in London till the eſtabliſhment of the Royal Society in 1662; and before that time, by the removal of ſome of the original members to Oxford, ſimilar meetings were held there, and thoſe ſtudies brought into repute in that univerſity. Mr. Boyle, who had entered upon his chemical ſtudies about the year 1647, was a principal perſon in the Oxford meetings: he publiſhed at that place his Sceptical Chemiſt, in 1661, and by his various writings and experiments greatly contributed to the introducing into England, a taſte for rational chemiſtry.

Next to Boyle, or perhaps before him as a chemiſt, ſtands his cotemporary the unfortunate Beccher, whoſe *Phyſica Subterranea*, juſtly intitled *opus ſine pari*, was firſt publiſhed in 1669. After having ſuffered various perſecutions in Germany, he came over into England, and died at London in 1682, at the age of 57. He reſided ſome time before his death in Cornwall, which he calls the mineral ſchool, owning that from a teacher, he was there become a learner. He was the author of many improvements in the manner of working mines, and of fluxing metals; in particular he firſt introduced into Cornwall the method of fluxing tin by means of the flame of pit-coal, inſtead of wood or charcoal *.

Lemery's very accurate courſe of practical chemiſtry appeared in

1675.

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* Beccher wrote his Alphabethum Minerale, at Truro in Cornwall, in 1682, not long before his death. In his dedication of this tract to Mr. Boyle, he has the following words:—"ignis uſus, ope flammarum lithantracum ſtannum et mineralia fundendi, Cornubiæ hactenus incognitus, ſed a me introductus."—This account which Beccher gives of himſelf, is not quite agreeable to what is advanced by an author every way qualified to come at the truth of this matter.—"Neceſſity at laſt ſuggeſted the introduction of pit-coal for the ſmelting of tin ore; and among others, to Sir Bevil Granville of Stow in this county, temp. Car. I. who made ſeveral experiments, though without ſucceſs; neither did the effectual ſmelting of tin ore with pit-coal, take place till the ſecond year of Queen Anne." Pryce's Miner. Cornub. p. 282.

1675. Glauber's works had been publiſhed at different times, from 1651 to 1661, when his tract, entitled Philoſophical Furnaces, came out at Amſterdam. Kunckel died in Sweden in 1702; he had practiſed chemiſtry for above 50 years, under the auſpices of the Elector of Saxony, and of Charles XI. of Sweden. He wrote his chemical obſervations in the German language, but had them tranſlated into Latin in the year 1677; the tranſlation is dedicated by its author to our Royal Society. They were afterwards tranſlated into Engliſh in 1704. Having had the ſuperintendency of ſeveral glaſs-houſes, he had a fine opportunity of making a great variety of experiments in that way; and I have been informed by our enamellers, and makers of artificial gems, that they can depend more upon the proceſſes and obſervations of Kunckel, than of any other author upon the ſame ſubject. The chemical labours of theſe and many other eminent men, too numerous to mention, were greatly forwarded by the eſtabliſhment of ſeveral ſocieties, for the encouragement of natural philoſophy, which took place in various parts of Europe about that period.

The Philoſophical Tranſactions at London, the Hiſtoire de l' Academie Royale des Sciences at Paris, the Saggi d' Eſperienze di Acad. del Cimento at Florence, the Journal des Sçavans in Holland, the Ephemerides Academiæ Naturæ Curioſorum, in Germany, the Acts of the

Academy of Copenhagen, and the Acta Eruditorum at Leypſic; all theſe works began to be publiſhed within the ſpace of twenty years from 1665, when our Royal Society firſt ſet the example, by publiſhing the Philoſophical Tranſactions. To theſe may be added, the works of the Academies of Berlin, Peterſburgh, Stockholm, Upſal, Bononia, Bourdeaux, Montpelier, Gottingen, and of ſeveral others which have been eſtabliſhed within the courſe of the preſent century. Near a thouſand volumes have been publiſhed by theſe learned ſocieties within leſs than 120 years. The number of facts which are therein related reſpecting chemiſtry, and every other branch of natural philoſophy, is exceedingly great; but the ſubject is ſtill greater, and muſt for ever mock the efforts of the human race to exhauſt it. Well did Lord Bacon compare natural philoſophy to a pyramid! Its baſis is indeed the hiſtory of nature, of which we know a little, and conjecture much; but its top is, without doubt, hid high among the clouds; it is "*the work which God worketh from the beginning to the end,*" infinite and inſcrutable.

By the light which has been incidentally thrown upon various parts of chemiſtry from thoſe vaſt undertakings of public ſocieties, as well as from the more expreſs labours of Stahl, Newman, Hoffman, Juncker, Geoffry, Boerhaave, and of many others equally worthy of commendation; by the theoretic concluſions and ſyſtematic diviſions which have been introduced into it; from the didactic manner in which the ſtudents of this art have been inſtructed in every medical ſchool; chemiſtry has quite changed its appearance. It is no longer conſidered merely in a medical view, nor reſtricted to ſome fruitleſs efforts upon metals; it no longer attempts to impoſe upon the credulity of the ignorant, nor affects to aſtoniſh the ſimplicity of the vulgar by its wonders, but is content with explaining them upon the principles of ſound philoſophy. It has ſhaken off the opprobrium which had been thrown upon it, from the unintelligible jargon of the alchemiſts, by revealing all its ſecrets in a language as clear and as common, as the nature of its ſubjects and operations will admit.

Conſidered as a branch of phyſicks, chemiſtry is but yet in its infancy: however, the mutual emulation and unwearied endeavours of ſo many eminent men as are in every part of Europe engaged in its cultivation, will in a little time render it equal to any part of natural philoſophy, in the clearneſs and ſolidity of its principles. In the utility reſulting to the public from its concluſions, with reſpect to the practice of medicine, of agriculture, arts and manufactures of every kind, it is even in its preſent ſtate inferior to none.

The uſes of chemiſtry, not only in the medical, but in every economical art are too extenſive to be enumerated, and too notorious to want illuſtration; it may juſt be obſerved,

ſerved, that a variety of manufactures, by a proper application of chemical principles, might, probably, be wrought at a leſs expence, and executed in a better manner than they are at preſent. But to this improvement there are impediments on every hand, which cannot eaſily be overcome. Thoſe who by their ſituations in life are removed from any deſign or deſire of augmenting their fortunes by making diſcoveries in the chemical arts, will hardly be induced to diminiſh them by engaging in expenſive experimental inquiries, which not only require an uninterrupted attention of mind, but are attended with the weariſomeneſs of bodily labour. It is not enough to employ operators in this buſineſs; a man muſt blacken his own hands with charcoal, he muſt ſweat over the furnace, and inhale many a noxious vapour before he can become a chemiſt. On the other hand, the artiſts themſelves are generally illiterate, timid, and bigotted to particular modes of carrying on their reſpective operations. Being unacquainted with the learned, or modern, languages, they ſeldom know any thing of new diſcoveries, or of the methods of working practiſed in other countries. Deterred by the too frequent, but much-to-be lamented examples of thoſe, who, in benefiting the public by projects and experiments, have ruined themſelves, they are unwilling to incur the leaſt expence in making trials, which are uncertain with reſpect to profit. From this apprehenſion,

prehenſion, as well as from the myſterious manner in which moſt arts, before the invention of printing, and many ſtill continue to be taught, they acquire a certain *opiniâtreté*, which effectually hinders them from making improvements, by departing from the ancient traditionary precepts of their art. It cannot be queſtioned, that the arts of dying, painting, brewing, diſtilling, tanning, of making glaſs, enamels, porcelane, artificial ſtone, common ſalt, ſal ammoniac, ſalt-petre, potaſh, ſugar, and a great variety of others, have received much improvement from chemical inquiry, and are capable of receiving much more.

Metallurgy in particular, though one of the moſt ancient branches of chemiſtry, affords matter enough for new diſcoveries. There are a great many combinations of metals which have never been made; many of which, however, might be made, and in ſuch a variety of proportions, as, very probably, would furniſh us with metallic mixtures more ſerviceable than any in uſe. The method of extracting the greateſt poſſible quantity of metal from a given quantity of the ſame kind of ore, has, perhaps, in no one inſtance been aſcertained with ſufficient preciſion. There are many ſorts of iron and copper ores which cannot be converted into malleable metals, without much labour, and a great expence of fuel; it is very probable, that by a well-conducted ſeries of experiments, more compendious ways of working theſe minerals might be found out. In our own times three new metallic ſubſtances have been diſcovered *, and their properties abundantly aſcertained by experiment; and it may reaſonably be conjectured, that future experience will yet augment their number. Till Marggraf ſhewed the manner of doing it, no metallic ſubſtance could be extracted from calamine, and all Europe was ſupplied with zinc † either from India or from Germany. A manufactory of this metallic ſubſtance has not many years ago been eſtabliſhed in our own country, and the copper works near Briſtol have ſupplied Birmingham

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[*] Platina, Regulus of Cobalt, Nickel.

[†] Zinc is a metallic ſubſtance, of the colour of lead; when united with copper, it conſtitutes braſs, pinchbeck, and other metallic mixtures reſembling gold.

ham with zinc extracted from calamine. *Black-jack* was not long ſince employed in Wales for mending the roads; its value is not yet generally known in Derbyſhire; but it is now well underſtood by ſome individuals to anſwer the purpoſe of calamine for the making of braſs*. Monſ. Von Swab in 1738 was, I believe, the firſt perſon who diſtilled zinc from *black-jack* †; and a work which he erected, probably gave the hint to the eſtabliſhers of our Engliſh manufactory: indeed, I have been well informed, that they purchaſed the ſecret from him when he was in England. The various kinds of black lead, from which neither tin nor iron can at preſent be procured to advantage; the mundicks, ſome cobalt ores, cawk, kebble, and other mineral ſubſtances, which are now thought to be uſeleſs, may ſome time or other, perhaps, be applied to good purpoſe. Cawk and kebble, which are found in great quantities in mining countries, eſpecially in Derbyſhire, and which are univerſally thrown away, may, perhaps, be nothing but different kinds of ſpar, and deſtitute of all metallic matter *; yet it may not be improper to remark, that the external appearance of the yellowiſh cawk is wholly ſimilar to that of calcined

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* The cobalt ores in Heſſe, which at preſent produce a net profit of about 1400l. a-year, were formerly uſed for the ſame purpoſe as black-jack was lately in Wales.—Born's Travels by Raſpe, Pre. xxvi.

† Cronſtedt's Miner. Sec. 231.

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* See Mr. Woulfe's ingenious Experiments in Philoſ. Tranſ. 1779, p. 15.

black-jack. That it is much of the ſame weight as *black-jack*, may appear from the annexed table:

Weight of a cubic foot of

White cawk	4047	avoirdup. oz.
Yellow cawk	4112	
Kebble	4319	
Black-jack	4093	
Water	1000	

In a word, the improvement of metallurgy, and the other mechanic arts dependent on chemiſtry, might beſt be made by the public eſtabliſhment of an Academy, the labours of which ſhould be deſtined to that particular purpoſe. The utility of ſuch eſtabliſhments has been experienced in Saxony and other places; and as mines and manufactures are to the full as important to us, as to any other European ſtate, one may hope, that the conſtituting a *Chemical Academy* may, in times of peace and tranquility, become an object not unworthy the attention of the King or the Legiſlature of the Britiſh nation *.

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* The reader who wiſhes to become more fully acquainted with the hiſtory of chemiſtry, may conſult what Borrichius has ſaid in his Diſſertation de Ortu et Progreſſu Chemiæ, publiſhed at Copenhagen in 1668; and in his book entitled Hermetis, Ægyptiorum, et Chemicorum ſapientia ab Hermanni Couringii animadverſionibus vindicata, publiſhed at the ſame place in 1674. He will alſo find ſomething worth his notice on this ſubject in Boerhaave's Chemiſtry; and in a work of Wallerius, called, Chemiæ Phyſicæ Pars Prima, publiſhed at Stockholm in 1760; where there is an uſeful catalogue of the moſt approved writers on the various parts of chemiſtry.

ESSAY II.

On the principal Terms and Operations uſed in Chemiſtry.

THIS Eſſay, in which I mean to give a general account of the principal terms and operations uſed in chemiſtry, will, perhaps, be more troubleſome to the reader, than any other which I ſhall have occaſion to write: but he muſt not be diſcouraged, nor conceive a diſguſt againſt the ſcience itſelf, from an inconvenience neceſſarily attending all ſciences. Chemiſtry has as few technical terms belonging to it, as navigation, law, medicine, or any other art or ſcience, which may have chanced to engage his attention. The more ancient chemiſts, indeed, were fond of coining abſtruſe terms, and frequent in the uſe of them; but this affectation is, at preſent, pretty generally and very juſtly exploded.

Of ſolidity and fluidity.

Though, in philoſophical propriety of ſpeech, water be as ſolid a body as a diamond, yet in the common acceptation of the word ſolidity, we conſider it as oppoſed to fluidity. Natural philoſophers have agreed to call that principle, by which the conſtituent parts of ſtones, glaſs, metals, and other ſubſtances cohere together, *Attraction*. They illuſtrate the agency of this principle, by a variety of deciſive experiments; deciſive as to the proof of the exiſtence of ſuch a power, but indicating nothing at all of the cauſe of it. As the unknown principle of mutual attraction between the conſtituent parts of ſolid bodies, is the cauſe of their *ſolidity*, ſo the unknown principle of fire, is the cauſe of their *fluidity*. I call the principle of fire unknown, becauſe, tho' its effects are ſufficiently manifeſt, the cauſe of it is wholly queſtionable. But in whatever manner fire may be ſuppoſed to exert its agency, it ſeems to be the great inſtrument of fluidity upon the ſurface of the earth. Without a certain degree of heat, water, ſpirits of wine, oil, quickſilver, and perhaps the air itſelf, would be converted into ſolid bodies; and with a certain degree of heat all fluid bodies would be changed into elaſtic vapours, and all ſolid bodies would either be wholly diſſipated, or in part diſſipated, and in part converted into fluid glaſs. Theſe are extreme caſes, to which no portion of the earth is obnoxious; no climate is ſo hot, but that it abounds with water in a ſtate of fluidity; and none has yet been diſcovered ſo cold, but that the air and the blood, of aquatic animals at leaſt, continue fluid in it.

Of volatility and fixity.

The changes produced in bodies by the action of fire are various, according to the conſtitution of the bodies themſelves, and the degree of heat to which they are expoſed. Some bodies, in a certain degree of heat, may be wholly diſſipated, others only in part, others not at all. Thus the ſame degree of heat which will intirely diſſipate camphor, and convert water into vapour, will only produce a partial diſperſion of the conſtituent principles of turpentine, blood, or milk; and will not effect any change or diminution of weight, in ſeveral woods, metals, earths, ſalts, and oils. Thoſe bodies which by heat ſuffer no diminution of their weight, are ſaid to be *fixed*, and thoſe which do loſe of their weight, are ſaid to be *volatile*; and they are ſaid to be more or leſs volatile, according as a leſs or a greater degree of heat is requiſite for producing a ſeparation of their parts. It is obvious, that *volatility* belongs to moſt bodies, ſolid as well as fluid; ſince the heat of the atmoſphere is ſufficient to diminiſh the weight of many, and artificial applications of ſuperior degrees of heat, that of many more: but it is not certain, whether abſolute *fixity* belongs to any body in nature, ſince the ſame body which is fixed in one degree of heat, may become volatile in another: thus diamonds, which remain unchanged in a ſmall degree of heat, may be wholly diſſipated in open veſſels by a greater; and gold, which can reſiſt the moſt violent fires excited in our furnaces, without loſing any thing of its weight, may not be able to ſuſtain the fiercer action of the ſolar rays, when united in the focus of a large burning-glaſs.

The fixity of bodies is not in proportion to their hardneſs, for a diamond is harder than a ruby, yet a diamond may be wholly diſſipated by a degree of heat which produces no manner of change in a ruby. We are indebted to the Emperor Francis I. for this experiment. He put diamonds and rubies, to the worth of ſix thouſand florins, into different veſſels, and expoſed them to a violent fire for 24 hours; at the end of that time the veſſels were taken out of the fire and opened, and there was not remaining the leaſt veſtige of the diamonds, the whole had been diſſipated; but the rubies were found to have undergone no ſort of change, either with reſpect to colour, ſhape, or weight*.

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[*] See Magaſin de Hambourg, Tom. xviii. p. 164. or an extract in the notes annexed to Henckel's Works, publiſhed at Paris in 1760, Vol. II. p. 413.—Similar experiments have

Of evaporation, volatilization, exhalation.

When ſolid or fluid bodies ſuffer a diminution of their weight, the parts which become volatile and fly away, are ſaid to be *evaporated*, *volatilized*, *exhaled*, for theſe three terms are often uſed promiſcuouſly, though it would be an eaſy matter to diſtinguiſh them. The parts themſelves are either humid, ſuch are thoſe which are ſeparated from all fluids, (except quickſilver) and the watery parts of ſolid bodies; or they are dry; ſuch are the volatile parts ſeparated from marble or chalk, during the burning of lime, from volatile ſalts,

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lately been made in France: See Chymie par M. Baumè, Vol. I. p. 105. A good tranſlation of this excellent work is much wanted.

ſalts, and reſins of various kinds, by the heat of the atmoſphere. The terms, evaporation, &c. as ſimply indicating a loſs of weight, may be applied to both. Evaporation is not ſolely effected by the mediation of heat; ſtrong dry winds in cold froſty weather, are often more powerful agents in promoting the evaporation of water and other fluids, than the greateſt heat of the ſun in ſummer. The ſuperficial parts of fluids are the only ones which are evaporated either by heat or air; and hence, in ſimilar circumſtances, the quantity evaporated, in any definite portion of time, will be greater as the ſurface of the fluid is greater. For this reaſon, the pans in which brine is boiled for the making of ſalt, and the pits, in which ſea water is evaporated by the ſun and air for the ſame end, are uſually made very ſhallow, and of a large area; and a proper attention to this circumſtance might be ſerviceable to ſugar-bakers, confectioners, and other artiſts who are under the neceſſity of evaporating large quantities of water. However, as a fluid contained in a deep veſſel, when heated to a certain degree, retains its heat longer than it would do, if it was ſpread over a ſhallower veſſel, and heated to the ſame degree; it may become a doubt, whether the quantity evaporated in conſequence of its retaining heat longer, may not be equal to or exceed the quantity evaporated from the ſhallower veſſel, in conſequence of its larger ſurface. It might, perhaps, be an uſeful problem to determine, by more accurate experiments than any which have been hitherto made, the length, breadth, and depth of a veſſel which, with the conſumption of a definite quantity of fuel, would evaporate the greateſt poſſible quantity of any fluid in a certain time.

Of diſtillation and ſublimation.

Though, in the proceſs of evaporation, the volatile parts of bodies are uſually diſperſed in the air, and the remaining ones only preſerved, yet it often becomes neceſſary to collect the volatile parts themſelves: when this is the caſe, proper veſſels are made uſe of for the purpoſe, and the operation, if the parts are fluid, is called, *diſtillation*, from their being collected drop by drop, *ſtillatim*. If the volatile parts, when collected, are dry and in a concrete form, the proceſs is called, *ſublimation*, from the parts being driven upwards by the force of the fire, and collected at a diſtance from the remaining parts. The volatile parts thus collected, may in general be called ſublimates; they are of different conſiſtencies, ſome being in hard maſſes, others in the form of a fine powder. Chemiſts have agreed to apply the name of *ſublimate*, to ſuch as are in conſiſtent maſſes, the others, they call *flowers*: thus we hear of *corroſive ſublimate*, and of *flowers of ſulphur*. The ſoot of a chimney is a matter ſublimed from the fuel, and it comes under the denomination of flowers, or ſublimate, according as it is of a powdery or conſiſtent appearance. During the ſmelting of lead ore, that impalpable ſubſtance which iſſues out of the chimney of the furnace, and falling upon the adjoining grounds, renders the graſs unwholeſome for cattle, may properly be called the flowers of lead ore. This diſtinction between diſtillation, as collecting the fluid, and ſublimation, as collecting the ſolid parts of bodies, is not always ſcrupulouſly adhered to; ſince the beſt authors ſpeak of the diſtillation of ſulphur, and of other bodies whoſe volatile parts are dry.

The chemiſts uſually diſtinguiſh diſtillation into three kinds, according to the different manners in which the diſtilled vapour is collected. The vapour in all caſes flies from the fire; hence when the fire is placed above the veſſel which contains the matter to be diſtilled, the vapour in eſcaping from the fire, will deſcend, and being collected in a proper veſſel, the diſtillation is ſaid to be made, ***per deſcenſum***, by deſcent. When the fire is placed under the veſſel containing matter to be diſtilled, the vapour will aſcend, and the diſtillation is called, ***per aſcenſum***, by aſcent; this is the common manner of diſtilling low wines and ſpirits. Beſides theſe two kinds of diſtillation, there is a third, which uſually takes its denomination from the form of the veſſel, in which the matter to be diſtilled, is put. This veſſel is bent, and hollow, ſomewhat reſembling in ſhape, a bullock's horn; it is from thence, called by the French, a ***cornue***; more generally, from its curved ſhape, a ***retort***. The lower and more capacious part of the retort is called its belly; this is ſometimes made almoſt globular, that it may contain the more; the tapering crooked part is called its neck, and this part is joined to the belly, with various degrees of obliquity, according to the uſe to which the retort is deſigned. A large pear, with a long bent neck, may give an idea of the ſhape of a retort. The matter to be diſtilled, be it liquid or ſolid, is put in at the neck: it deſcends into the belly of the retort; the heat is applied to the belly; the vapours in flying from the heat, ſtrike againſt the upper ſide or roof, as it is called, of the retort; finding no exit there, they are forced out laterally through the neck; the neck of the retort is cloſely joined to another hollow veſſel, which from its office, in collecting the diſtilled vapour, is called the *receiver* or *recipient*; the diſtillation is ſaid to be made, *per latus*, by the ſide, or *per retortam*, by the retort. The retorts are made of various materials, as of glaſs, iron, earth, according to the degree of heat to which they are to be expoſed.

It is not certainly known when, or by whom, the art of diſtilling was firſt found out. A diligent ſearcher into antiquity, informs us, "that about the year 1150, the Moors of Spain firſt introduced the art of diſtillery into the weſt of Europe, they having learned it from the African Moors, who had it from the Egyptians; but how long before the ſaid African Moors had been in poſſeſſion of this curious art, does not clearly appear. Certain it is that this art was not known to the ancient Greeks and Romans, ſince neither Pliny, nor any other Latin or Greek author makes mention of it*."

To me it ſeems probable that the art of ſublimation was known before that of diſtillation. The term *alembic* or *alambic*, is compounded of the Arabic particle *al* (the), and the Greek word *ambix*, a kind of cup, or cover of a pot; it is now uſed to denote the whole of a certain diſtilling apparatus; it formerly denoted only one part of it, namely the head, or that part in which the diſtilled matter was collected. Dioſcorides is thought, by Suidas, to have been phyſician to the celebrated Queen Cleo-

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[*] Anderſon on Comm. Vol. I. p. 83.

Cleopatra; he certainly knew the manner of ſubliming quickſilver from its ore, and he calls that part of the apparatus, in which the ſublimed quickſilver was collected, ambix*; the addition of a ſpout or beak to his ambix, would have furniſhed him with a complete inſtrument for diſtilling, as well as ſubliming. But no one who conſiders how near the ancients were to the diſcovery of printing without finding it out, can be ſurpriſed at their knowing ſublimation, and at the ſame time being ignorant of diſtillation; for that Dioſcorides was ignorant of the art of diſtilling, may be reaſonably conjectured, when we conſider the ſad ſhift he was put to in order to collect an oil which aroſe from boiling

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* L. v. c. 110.

ing pitch; he orders a clean fleece of wool to be ſtretched over the pot in which the pitch was boiled, and the oil to be preſſed out of the wool as often as it became ſufficiently wet with it.

It muſt be owned, that this argument is not intirely concluſive againſt the opinion of thoſe who think that the art of diſtillation was known to the more ancient Greeks and Romans. For Dioſcorides might have had his reaſons for making uſe of the contrivance here mentioned, though he had been acquainted with diſtillation. It ſeems moſt natural to expect ſome account of this proceſs in the writings of the phyſicians Hippocrates and Galen, had they been acquainted with it; but there are no paſſages in their works, from which any certain concluſion can be drawn relative to their knowledge of this operation. Geber, the Arab, was well acquainted with it, for he has given us a chapter on the ſubject, in which he lays down rules for diſtilling *per deſcenſum*, and *per aſcenſum*, but he ſays nothing of diſtillation *per retortam*. But diſtillation was known, to the Egyptians at leaſt, ſome centuries before the age of Geber; for Zoſimus of Panopolis in Egypt, who lived in the fourth century after Chriſt, if not ſooner, has exhibited ſome figures of a diſtilling apparatus [*]. Of

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[*] Theſe figures may be ſeen in Borrichius' Hermetis et Ægyptiorum ſapientia, p. 156. The word *Chemia* firſt occurs in the works of this Zoſimus. He ſays, though one may wonder whence he got his information, that it was in uſe before the Deluge, and that it ſignifies

Of dephlegmation, concentration, rectification.

The word *phlegm* uſually denotes the moſt watery parts of bodies, and when theſe parts are ſeparated, either wholly, or in a great degree, either by diſtillation or ſublimation, the

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ſignifies ſomething concealed. The Arabic tongue, according to Bochart, furniſhes us with the word *Kémi* ſignifying concealment, and thence he derives *Chemia*, rather than from *Cham* the Hebrew root. Egypt is called by Plutarch in *Oſiride*, Chemia, which Ortelius expounds for Chamia, from Cham the ſon of Noah. As the Arabians do not always copy exactly the proper names they borrow from the Hebrew; may it not be conjectured, that the Arabic *Kémi* ſignifying concealment, was introduced into that language, from the ſecret and hieroglyphic manner, in which the prieſts of Cham (Egypt,) concealed their knowledge of chemiſtry and other arts?

the bodies, be they ſolid or fluid, are ſaid to be *dephlegmated*. When the watery parts of any compound fluid, are by any means taken away, the remaining parts approach nearer to each other, and may on that account be ſaid to be *concentrated*; though the term concentration is chiefly applied to the ſeparation of water from acid liquors. It frequently happens that the products obtained by one operation, are not ſufficiently pure and homogeneous, and that a ſecond or third diſtillation or ſublimation becomes neceſſary to exhibit them in a proper form: this proceſs of purifying the ſame body, how often ſoever it be repeated, is called *rectification*. Thus when we hear of an oil, or volatile ſalt, eight or ten times rectified, we are to underſtand that it has been ſo often rediſtilled or reſublimed. If the impurity, to be taken away, be a ſimple phlegm, it is obvious that the terms rectification, concentration, and dephlegmation, may be ſynonymous; and indeed they are often uſed promiſcuouſly. Thus weak vinous ſpirits, and weak vinegars, are rectified, concentrated or dephlegmated by froſt; for the water contained in theſe fluids being frozen and taken away in the form of inſipid ice, the remaining fluids become ſtronger.

Of the degrees of heat commonly uſed in chemiſtry.

From what has been ſaid relative to the fixity and volatility of bodies, it may readily be conceived, that the operations of diſtillation, and ſublimation, by which the volatile parts of bodies are collected, will require different degrees of heat, according to the nature of the body whoſe parts are to be diſtilled or ſublimed. It would be endleſs to enter into all the fancies and contrivances of chemiſts upon this ſubject; yet there are four modes of applying heat, which, though they are not ſo well defined that the degree of each can be accurately aſcertained, ought to be particularly noticed, — *the heat of boiling water*; — *a ſand heat*; — *a naked fire heat*; — and *a ſolar heat*.

Water, highly rectified ſpirits of wine, and other homogeneous fluids, cannot be heated in open veſſels, and in a given ſtate of the air beyond a certain degree peculiar to each. As ſoon as they fully boil, no continuance or in-

increaſe of fire can communicate to them any increaſe of heat; hence a veſſel, containing a body to be diſtilled, being expoſed to the action of boiling water, all the parts of the body which are volatile, with the degree of heat in which water boils, will be elevated from the body*, and may be collected in proper veſſels, whilſt the other parts, if the body conſiſts of different principles, will remain at the bottom of the veſſel. This heat of boiling water is one of the moſt definite degrees known in chemiſtry ; there are many delicate operations, eſpecially on vegetables, in which it would be improper to uſe ſo great a heat as that of boiling water; but it is not neceſſary to enlarge upon

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* This obſervation is not, probably, perfectly juſt.---It is a very remarkable phenomenon, that a veſſel containing water will never *boil*, how long ſoever it be expoſed to the action of *boiling* water. The reader may convince himſelf of this by an eaſy experiment. Fill a common bottle with water, put the bottle thus filled into a pan of water, ſo that the mouth of the bottle may be a little above the water in the pan; ſet the pan on the fire, and when the water in the pan boils in the moſt violent manner, that in the bottle will be obſerved not to boil, and if its heat be examined by a thermometer of Fahrenheit's

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Fahrenheit's ſcale, it will not be found to amount to above 202 degrees, whilſt that of the boiling water in the pan is 212 degrees. Hence it ſhould ſeem, that bodies, diſtilled in veſſels expoſed to the action of boiling water, do not experience the heat of boiling water. This phenomenon is mentioned from Bartholin's Acta Medica, in the Philoſ. Tranſ. for 1673, No. 97.—See alſo Profeſſor Braun's Exper. Nov. Comm. Petrop. Tom. XII. p. 289.—and Rozier's Journ. 1773.

on this obſervation in this place. Boiling mercury, boiling lead, boiling copper, would afford other definite degrees of heat; and boiling oil might be very properly uſed as a mean of diſtilling bodies, notwithſtanding that oil thickens in boiling, and thereby becomes hotter as the more ſubtle parts are diſperſed.

There are many bodies, and parts of bodies, which cannot be rendered volatile by the heat of boiling water; theſe are uſually diſtilled by immerſing the veſſel containing them in ſand, and applying the fire ſo as to heat the ſand; for the ſand gradually communicates its heat to the veſſel which it touches: the ſand is generally put into an iron pot; it is evident, that the fire which is employed to heat the pot, may communicate any degree of heat to the ſand, from the ſmalleſt, to that which is ſufficient to melt the iron, ſo that it would no longer hold the ſand.---When the heat is communicated to the veſſel, containing the body to be diſtilled, through any medium, as that of boiling water, or hot ſand, the body is ſaid to be diſtilled in a water bath, or ſand bath, the chemiſts having agreed to call the medium, ſerving for the communication of heat to the diſtilling or ſubliming veſſel, a bath; and formerly, beſides water and ſand, they uſed vapour, iron filings, wood aſhes, &c. for this purpoſe.

When neither the heat of boiling water, nor of ignited ſand, is ſufficient to ſeparate the volatile parts of a body from the remainder; the veſſel containing the body is exposed to a naked fire; that is, it is ſurrounded with burning fuel, and by a contrivance in the ſtructure of the furnace, the flame of the fuel is often made to reverberate upon it. This degree of heat is alſo indefinite; it may be augmented, by bellows and other means, to ſuch a pitch as to melt the furnace containing the fuel, or the veſſel containing the body to be diſtilled. The degree of heat which may be excited in furnaces is undoubtedly very great, yet it is far inferior to that of the ſun's rays when collected into a focus by a burning glaſs or ſpeculum: the force of this ſolar heat cannot, perhaps, be ſubject to any other limit, except what ariſes from the difficulty of forming large ſpeculums.

Of ſolution, ſaturation, and chryſtallization.

When the parts of a ſolid body, as common ſalt or ſugar, are ſo united to a fluid, as water, that they compoſe with it an apparently homogeneous fluid, remain ſuſpended in it, and do not deſtroy its tranſparency, the ſolid body is ſaid to be *diſſolved* in the fluid; the operation is called *ſolution*; the fluid, being looked upon as the principal agent in diſſolving the body, (though all action is mutual and equal) is called the *ſolvent*, or more commonly, according to ſome ſilly or indelicate ideas of the alchemiſts, the *menſtruum*; the compound reſulting from the union of the fluid and the body, is called a *ſolution* of this or that body, in this or that *menſtruum.* Thus we ſpeak of a ſolution of common ſalt or ſugar in water, of a ſolution of ſulphur in oil of turpentine, of camphor in ſpirits of wine, of ſilver in aqua fortis, and ſo on. The term ſolution is alſo ſometimes applied to the union of two fluids; thus the air is ſaid to be diſſolved in water, becauſe all natural water contains air; and water is ſaid to be diſſolved in air, becauſe the moſt tranſparent air contains a conſiderable portion of water: thus alſo various ſorts of oils are ſaid to be diſſolved in ſpirits of wine. And laſtly, ſolution is applied to the union of two ſolid bodies: thus glaſs is a compounded body reſulting from the mutual ſolution of an earth and a ſalt.

It may be worth while to explain, a little more fully, the firſt and moſt obvious notion of ſolution; that in which a ſolid body is united to a fluid. If you take an ounce of common ſalt, and throw it into a quart of water, it will fall to the bottom of the water, as an ounce of ſand or chalk would do; but it will not, like them, ſtay there; in a very little time, eſpecially if the water be ſtirred, the ſalt will intirely diſappear, it will be uniformly diſperſed through the whole body of the water, no one drop of water will contain more particles of ſalt than another, nor will any of them contain ſo much ſalt as it is able to do. For if you add another ounce of ſalt, that alſo will be diſſolved, but not quite ſo ſpeedily as the firſt; and that will alſo be uniformly diffuſed through the whole body of the water, ſo that each drop of water will now contain twice as much ſalt as it did before. This power which the water has of taking up and keeping ſuſpended the particles of ſalt is not unlimited; you may add ſo much ſalt to it, that it will not diſſolve one particle more: the water in that ſtate is properly enough ſaid to be *ſaturated*. All other menſtruums are likewiſe ſaid to be ſaturated, when they will not take up and keep ſuſpended any more of the body diſſolved in them: thus a pint of ſpirits of wine will only take up a definite portion of camphor; a pint of oil of turpentine will only keep diſſolved a definite portion of ſulphur; and a pint of aqua fortis will be ſo ſaturated with a definite portion of ſilver, that it will have no ſort of action upon any additional quantity which ſhall be put into it.

We do not know either the ſize or the ſhape of the particles of water, nor whether they are contiguous to each other, nor how they come to attract the particles of ſalt more ſtrongly than they attract each other; but it is, notwithſtanding, to this prevalent *attraction*, that we attribute the ſolution of the ſalt in water, and of every other body in its proper menſtruum. We are certain that every particle of water attracts to itſelf, and keeps ſuſpended a particle of ſalt, of a definite weight; otherwiſe an equal number of theſe particles, conſtituting drops or particles of equal bulks, would not have equal weights, nor contain equal quantities of ſalt, which we are certain they do. Now if we ſuppoſe a ſingle particle of water to be evaporated, or any how taken away from a ſaturated ſolution of ſalt, then the particle of ſalt which was kept ſuſpended by the attraction of that particle of water, muſt of neceſſity have a tendency to fall down to the bottom; becauſe every other particle of water, being ſuppoſed to have as much ſalt united to it as it is able to ſuſtain, can contribute nothing to its ſupport; and if inſtead of one particle of water we ſuppoſe a thouſand, or ten hundred thouſand to be evaporated, then will a thouſand, or ten hundred thouſand particles of ſalt be left without any ſubſtance to ſupport them; and having no ſurrounding fluid to hinder their mutual attractions from taking place, they will coaleſce together upon the ſurface of the ſolution from which the water has been evaporated, and by their union conſtitute a ſaline pellicle, which will be viſible to the naked eye. This pellicle, as ſoon as it becomes heavy enough to overcome the tenacity of the fluid upon which it floats, will by its gravity deſcend from the ſurface where it was formed, to the bottom of the veſſel containing the ſolution; or, meeting with aſperities on the ſides, it may attach itſelf in part to them.

But the taking away a part of the diſſolving fluid is not the only mean by which the particles of the diſſolved body may be made to unite; there is another, and in many inſtances, full as efficacious a one, the taking away a part, not of the ſubſtance, but of the heat of the diſſolving fluid. Thus if you put into a quart of boiling water as much ſaltpetre as it will diſſolve, and filling a bottle with the boiling ſolution, inſtantly cork it up; then you are ſure that no part of the water can eſcape; and if the diminution of the quantity of a menſtruum was the only way by which the parts of the diſſolved body could be made to unite, then would the particles of the diſſolved ſaltpetre, in this inſtance, not unite at all, ſince there can be no diminution of the quantity of the diſſolving water: you will, however, on the contrary, obſerve the particles of the ſalt coaleſcing together, as the ſolution grows cold, and forming large and regular cryſtals.

—The word *cryſtal* is derived from the Greek words *cryos*, froſt, and *ſtellω*, to contract. The ancients ſuppoſed a particular mineral known by the name of *rock cryſtal*, to be nothing but congealed water; this mineral is of a determined angular figure, and hence all ſalts and other ſubſtances which, from being diſſolved in menſtruums, or fuſed in fire, concrete into regular figures, are ſaid to be *cryſtallized*.

There are a great many circumſtances relative to the manner in which different ſalts cryſtallize, which cannot be inſiſted on in this place; one thing deſerves particularly to be remarked,—that every ſalt in cryſtallizing, invariably aſſumes its own peculiar form. You may diſſolve common ſalt, or ſaltpetre, a thouſand times, and cryſtallize them as often by evaporating or cooling the water in which they are diſſolved, yet will you ſtill find the common ſalt will be conſtantly cryſtallized in the form of a cube, and the ſalt petre in the form of a priſm; and if you examine with a microſcope ſuch ſaline particles as are not viſible to the naked eye, you will obſerve theſe particles to be of the ſame ſhape with the larger maſſes. The definite figure appropriate to every particular ſpecies of ſalt, may admit a little variety from the accidental admixture of other bodies, or from ſome ſingular circumſtances attending the evaporation and cryſtallization of the ſolution; but theſe varieties are foreign to the nature of the ſalt, and are not greater than what attend almoſt every ſpecies of vegetables, and even of animals, from change of food and climate.

Here a large field of inquiry opens to our view; and though it be better, as Seneca has it, *de re ipſa quærere quàm mirari*; yet all our attempts to inveſtigate the works of God, are weak and ineffectual: we feel his interference every where, but we cannot apprehend the nature of his agency any where. A blade of graſs cannot ſpring up, a drop of rain cannot fall, a ray of light cannot be emitted from the ſun, nor a particle of ſalt be united, with a never failing ſymmetry, to its fellow, without him: every ſecondary cauſe we diſcover, is but a new proof of the neceſſity we are under of ultimately recurring to him, as the one primary cauſe of every thing. Yet notwithſtanding this our utter inability to ſearch far into the nature of things, philoſophical inquiries are by no means without their uſe. He who finds his endeavours to comprehend the works of *creation*, checked at every turn; who underſtands that every the minuteſt part of this little earth, which is itſelf nothing, as it were, when compared with the infinity of the divine works, is to him one great miracle; willnot be over-zealous in affirming that God cannot interfere by his *providence*, in the management of what he hath made, or that he has interfered in this or that particular way. In the conſcious abaſement of his own intellect, which philoſophy will have taught him, he will be cured of all attachment to ſyſtem, whether it be a ſyſtem of bigotry or infidelity: he will not be fond of anathematizing every one who cannot think with him in religious matters; nor, on the other hand, will he contend that a revelation from God muſt be an impoſſibility, from any abſtract notions he may have framed of the nature and works of the Supreme Being. But to return to our ſubject.

If what has been ſaid relative to cryſtallization, be not perfectly intelligible to the reader, I would adviſe him to make the following eaſy experiment, which will give him a better notion of the matter than a thouſand words. Into a baſon full of boiling water, put as much ſaltpetre as the water will take up; if the ſaltpetre was purified, the tranſparency of the water will not be injured, it will ſtill appear to be an homogeneous fluid: when the water will take up no more ſaltpetre, then he may conclude that it is ſaturated: let it ſtand without being ſtirred, till it grows cold. As it cools, a great many cryſtals, all of the ſame ſhape, may be ſeen ſhooting out from the ſides and bottom of the baſon, and increaſing in ſize till the ſolution becomes quite cold. When no more cryſtals can be formed by that degree of cold which prevails in the apartment where the experiment is made, pour the liquor from the ſolid cryſtals; this liquor is ſtill ſaturated with ſaltpetre; and in order to make it part with more of its ſaltpetre, ſome of the water which keeps it diſſolved muſt be evaporated: upon the taking away a part of the water, a correſpondent part of the ſaltpetre loſes the power by which it is ſuſpended, and ought, upon that preſumption, inſtantly to fall to the bottom: yet it muſt be remembered, that the water from its increaſed heat during the evaporation, is able to ſupport more ſaltpetre than if it was cold; and therefore the ſaltpetre will not begin to cryſtallize, notwithſtanding the loſs of part of its menſtruum, till the remainder begins to cool. By repetition of this proceſs of evaporation and cryſtallization, we may obtain all the ſaltpetre which was at firſt diſſolved, as no portion of it can be evaporated with that degree of heat which is uſed in evaporating the water.

Of mixture and filtration.

There is a difference between *ſolution* and *mixture* ſufficiently obvious, though not always attended to.--- Thus water which ſprings from chalk, has often, when the ſprings are low, a milky caſt, ariſing from ſome very fine particles of chalk which are *mixed* with it, but not *diſſolved* it; in for perfect ſolution is always accompanied with tranſparency. Briſtol and Matlock waters are very tranſparent, though they contain a large portion of earth; but the earth is in the ſtate of a ſalt, and perfectly diſſolved in them.--- Turbid waters, turbid ſolutions of ſalts, and other liquors which contain, mixed with their ſubſtance, any heterogeneous matter, are purified to a certain degree by *filtration*; that is, by being made to paſs through certain ſubſtances, whoſe pores are large enough to give a paſſage to the particles of water, and to the particles of any ſalt diſſolved in water, but not to the earthy or oily fœculences which may happen to be mixed with it. The ſubſtances made uſe of are called *filters*; they are either ſand, or a porous kind of ſtone, thence called a filtering ſtone, or flannel, or linen, or leather, or brown paper into the compoſition of which no ſize has entered. This laſt ſubſtance is generally uſed in ſmall chemical experiments; it is made up into a conical form, and placed in a funnel, or other convenient inſtrument to ſupport it. Filters are ſerviceable inſtruments, not only for the purifying of liquors, but for the ſeparating of any kind of ſalt from a mixture of ſalt and earth, and enabling us to aſcertain the proportion of ſalt and earth contained in any propoſed ſpecimen. An inſtance will illuſtrate my meaning. It is commonly known, that wood aſhes, fern aſhes, and the aſhes of moſt vegetables, conſiſt partly of a particular kind of ſalt, partly of earth. Suppoſe it was required to determine the proportion of ſalt and earth contained in any ſpecimen of aſhes, the proceſs muſt be conducted in the following manner: — Take a pound of the aſhes, previouſly well dried, boil them in a quart of water, pour the water and the aſhes into a filter, the water will paſs through the filter, bringing with it the ſalt contained in the aſhes; for water diſſolves all kinds of ſalt, and no kind of earth: the earth therefore of the aſhes will be left in the filter: waſh the earth remaining in the filter, by pouring upon it hot water, till the water, in filtering through it, comes off wholly without taſte; then evaporate all the water in which the aſhes were boiled, and with which the earth in the filter was waſhed, and when all the water is diſſipated, there will be left a greyiſh kind of ſalt, of a very pungent taſte. When this ſalt has been dried as much as the aſhes were, it muſt be weighed whilſt warm from the fire, and its weight noted; then dry in the ſame manner the earth remaining in the filter; and the weight of the earth thus dried, added to the weight of the ſalt, which has been extracted, will, when the experiment has been properly made, amount to the weight of the aſhes employed in making it.

Of the analyſis of bodies.

Moſt of the bodies which we meet with upon the ſurface of the earth or below it, are compounded of heterogeneous principles; theſe principles muſt, in many inſtances, be ſeparated from each other, before either the nature of the body can be properly underſtood, or the principles themſelves be applied to any uſeful purpoſe. Thus the juice muſt be preſſed from the earthy part of the grape, the ſugar-cane, and the olive, before we can obtain either wine, ſugar, or olive oil. The ſaline matter muſt be extracted from the earthy part of the

the aſhes mentioned in the laſt experiment, before it can in many caſes become uſeful as a ſalt. Sulphur or arſenick, or both, muſt in many inſtances be ſeparated from the ores of metallic ſubſtances, with ſingular care, before the metallic ſubſtances themſelves can become articles of commerce; or even before their exiſtence, as conſtituent parts of the ores, can be made apparent. Many bodies, without any aſſiſtance from art, ſpontaneouſly reſolve themſelves into diſtinct principles; thus blood, by ſtanding, becomes ſeparated into a watery fluid, and a red fleſhy ſubſtance; milk reſolves itſelf in like manner into cream, into curd, and into whey. The proceſs by which the heterogeneous parts of a compound body are ſeparated from each other, whether it be carried on by nature or art, may be called the *analyſis*, *reſolution*, or *decompoſition* of the body.

It frequently happens, that the parts ſeparated by one analyſis, are themſelves compounded bodies, and capable of being reſolved, by a further proceſs, into more ſimple principles. Juſt as in language, a ſentence may be reſolved into words, words into ſyllables, and ſyllables into letters ; ſo in the decompoſition of natural bodies, we at laſt arrive at principles which do not admit any further reſolution or change. Theſe ſimple, unchangeable principles are called *elements* ; and it may, from what has been advanced, be readily apprehended, that the ſame ſubſtance may be eſteemed an element by one man, which is not ſo eſteemed by another, according to the difference of their ſkill exerted in the analyſis of bodies.

Of chemical elements.

By chemical elements, which are the laſt products of chemical analyſis, we are to underſtand, not very minute indiviſible particles of matter, but the ſimple homogeneal parts of bodies which are not capable, as far as our experience teaches us, of any farther reſolution or diviſion, except in a mechanical ſenſe, into ſimilar parts leſs and leſs without end, as water into vapour more or leſs ſubtile and attenuated. Ariſtotle and his followers eſteemed *earth*, *air*, *fire*, and *water*, to be elements, ſimple and uniform in their ſeveral kinds, eſſentially diſtinct, and utterly incapable of being converted into one another, yet eaſily uniting together, and by their different arrangements, proportions, and mixtures, compoſing every body in the univerſe. Many modern chemiſts have adopted this idea; others have increaſed the number of elements, by adding a ſaline principle; others have contended, that ſome of theſe elements, air and fire for inſtance, are themſelves compound bodies; and others, laſtly, are perſuaded, that there is only one elementary homogeneal matter, and that all the varieties of bodies, as well as of what are commonly eſteemed elements, ought to be attributed to the different magnitudes and figures of the particles compoſing them; and as the component parts of water and air, or any other body, are by no means ſuppoſed to be elementary particles of matter, but to be made up of different numbers of elementary particles arranged in different forms, it may be thought probable, that mechanical cauſes may either diminiſh or augment the number, or change the diſpoſition of the particles, and thus effect the ſeveral varieties obſervable in nature.

It would be improper in this place to enlarge on a ſubject, concerning which both ancient and modern philoſophers have been ſo much divided in opinion: Their great diverſity of ſentiment may ſuggeſt a ſuſpicion, that the full comprehenſion of it does not fall within the reach of the human underſtanding. The following obſervation may, perhaps, tend a little to illuſtrate this matter. Let us ſuppoſe that this terraqueous globe was not ſurrounded with any air or atmoſphere, and that, by an approach to the ſun, or an increaſe of the ſubterraneous fires, by ſome means or other it ſhould become expoſed to a heat four times greater than the medium heat of our ſummer, which we may reckon to be about 60 degrees of Fahrenheit's thermometer; then would an atmoſphere be quickly formed around it: all the water upon its ſurface, moſt of the juices of plants and animals, and a great variety of mineral particles, would be raiſed up in vapours and exhalations, and whilſt the heat continued would be kept ſuſpended in an elaſtic ſtate, and conſtitute an atmoſphere analogous, as it may ſonably be imagined, to the chaotic ſtate of our preſent atmoſphere, only differing from it in this; that it would require a greater degree of heat, in order to keep the particles of matter from coaleſcing into one heterogeneous maſs. Again, in the preſent ſtate of the atmoſphere, ſuppoſe that a great degree of cold ſhould continue unabated for any length of time; all the water upon the ſurface of the earth would be changed into a ſolid tranſparent ſtone, which might be dug out of its quarry, and employed in building, as well as marble, or any other ſpecies of ſtone; all the particles of air would be brought cloſer together; ſome of them, which were the leaſt elaſtic, would be re-united; and imagining the cold to be indefinitely increaſed, what reaſon can there be againſt ſuppoſing that the whole atmoſphere would be reduced into a ſolid ſtate, forming an heterogeneous cruſt upon the ſurface of the earth: the thickneſs of this cruſt, ſuppoſing it to be as denſe as marble, would be about four yards? It will eaſily be underſtood, that water, and air, and earth, are, upon this hypotheſis, but variations of the ſame element introduced by heat.

That the atmoſphere which ſurrounds the earth, was originally formed from the chaotic maſs, by having the more ſubtile parts of which that maſs conſiſted, elevated and put into an elaſtic ſtate by means of heat, ſeems not altogether improbable. We find the atmoſphere or firmament immediately ſucceeding the formation of light; now, if the effect of that light was heat, be the form or matter of it what you pleaſe, then would ſuch particles of the ſhapeleſs jumble, as were capable of being evaporated with that degree of heat, be elevated in an elaſtic ſtate, and a diviſion or ſeparation would be made in the midſt of the great abyſs, between the waters which were of a nature ſubtile enough to be converted by that degree of heat into an elaſtic fluid, conſtituting the firmament or atmoſphere, and the waters which could not be evaporated in that degree of heat, but ſtill remained covering the ſurface of the globe, being not collected into one place, that the dry land might appear, till the third day. This notion of the atmoſphere and its formation, ſeems to be conformable enough to Newton's opinion, expreſſed in his letter to Mr. Boyle. "I conceive the confuſed maſs of vapours, air, and exhalations, which we call the atmoſphere, to be nothing elſe but the particles of all ſorts of bodies of which the earth conſiſts, ſeparated from one another, and kept at a diſtance by the ſaid principle*,"—a principle of repulſion.

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* Boyle's Life prefixed to the fol. edit. of his Works, p. 71.

ESSAY III.

Of ſaline Subſtances.

IT may be expected that this diſquiſition ſhould be commenced by giving a rigid definition of the term ſalt, or ſaline ſubſtance. But the complex ideas of natural ſubſtances are not ſubject to very definite deſcriptions. Nature, in her ſeveral productions, proceeds by imperceptible gradations, ſeldom leaving any deciſive marks, by which we can invariably diſcriminate them into ſorts. The two moſt general ideas which appertain to the word ſalt, are *ſapidity* and *ſolubility* in water, and ſome add, want of inflammability in fire. Every ſubſtance ſoluble in water, and affecting the organ of taſte with a ſenſation different from that excited by its weight, may be called a ſalt: I am ſenſible that this deſcription of a ſalt cannot in all caſes be cloſely adhered to, without confounding things ſufficiently diſtinct. Copper by long maſtication excites a nauſeous taſte, and by lying long in water it is in part diſſolved in it, and yet we are not accuſtomed to claſs copper among ſaline ſubſtances.

If any one ſhould wiſh to extend the meaning of the term ſalt, by applying it to all bodies which have regular figures, from ſome obſcure notion, that a ſaline principle is the univerſal cauſe of cryſtallization, then a variety of ſpars and precious ſtones, glaſſes, and metallic ſubſtances, which are neither ſapid nor ſoluble in water, would be rightly denominated ſalts; and water itſelf, when concreted into ice, would come under the ſame appellation. But leaving this more enlarged ſignification of the word ſalt, to the contemplation of thoſe who are ſtudious in the formation of ſublime ſyſtems of nature; and confining ourſelves to the more obvious properties of ſapidity and ſolubility in water as characteriſtic of ſaline ſubſtances; we may proceed to obſerve, that all ſalts may be reduced to one or other of the three following kinds; they are either,—*acid ſalts*—*alkaline ſalts*—or *neutral ſalts*.

Of acids.

The term *acid* explains itſelf by its ordinary acceptation; for tho' there may be a great diverſity in the taſtes excited by different acid bodies, both with reſpect to intenſeneſs and quality, yet no language has furniſhed diſtinct names for this variety. Sorrel, vinegar, cream of tartar, lemons, tamarinds, and a great many other bodies are all ſaid to be acid when taſted; and this capacity of exciting an acid taſte, is one characteriſtic of an acid ſalt.

All thoſe bodies, with a very few exceptions, which have an acid taſte, have alſo, when ſufficiently purified, the property of changing the blue colours of vegetables, as of ſyrop of violets into a red; and hence this quality is reckoned another characteriſtic of an acid ſalt.

The great diviſion of all terreſtrial ſubſtances into minerals, vegetables, and animals, called the three kingdoms of nature, has ſuggeſted to chemiſts a diviſion of acids into *mineral*, *vegetable*, and *animal acids*, according to the nature of the ſubject from which they are produced. The mineral acids may be copiouſly ſeparated, by diſtillation, from *vitriol*, *nitre*, and *ſea ſalt*; and in reference to theſe ſubſtances, they are uſually called the *vitriolic acid*, the *nitrous acid*, and the *marine acid*. —The vegetable acids are either *native*, ſuch as exiſt in ſour fruits and plants; or *factitious*, ſuch as *vinegar* and *tartar*, which are produced by fermentation. To the claſs alſo of factitious vegetable acids, may be referred all the acids ſeparable from vegetable matter by diſtillation; theſe generally retaining a burnt ſmell, are called *empyreumatic* acids: they have not hitherto been ſo fully examined as to be claſſed into different ſpecies. Animal acids are ſuch as may be ſeparated from various parts of animals by diſtillation; or they are ſuch as bees, ants, and ſome other inſects, contain in proper veſſels ready prepared, and which they eject in ſtinging.

Of alkalies.

The term *alkali* is compounded of the Arabic particle *al* (the) and *kali*, the Arabic name of a maritime plant called by us *glaſſwort*, or *marſh ſamphire*. Glaſſwort is diſtinguiſhed by botaniſts into the greater or leſſer jointed glaſſwort, ſnail-ſeeded glaſſwort, prickly glaſſwort, &c. all of which are called kali; and from the aſhes of them all, when thoroughly calcined, there may be waſhed out a ſalt, which is called an *alkali*, or an *alkaline ſalt*. If any one ſhould think that the word kali is derived from an Hebrew root of nearly the ſame ſound, ſignifying to burn; then he will conclude, that alkali originally had reference not to the name of any particular ſpecies of plants, but to the manner in which a ſalt might be procured from the aſhes of burnt vegetables in general; and that in proceſs of time a certain kind of plants came to be called kali, from its aſhes abounding more, than thoſe of any other plant, with ſalt; juſt as *ſoda* or *ſoude*, from being the common name for this very ſalt, which is ſeparated from kali, has become the French name for the plant itſelf *.

Kali is not the only maritime plant which yields an alkaline ſalt. On the coaſt of Spain, about Alicant and Carthagena, and, indeed, in many other countries bordering on the Mediterranean, the farmers ſow their lands with the ſeeds of different ſorts of maritime plants, which they pluck up at the proper ſeaſon, dry in the ſun as we dry hay, and burn to aſhes. About Carthagena they principally cultivate four ſorts of plants, *barilla*, *gazul* or *algazul*, *ſoza*, and *ſalicornia*. The barilla yields the pureſt fixed alkali; each root of this plant ſends out a great many ſtalks reſembling ſamphire, and riſing to about the height of four inches. The ground is much exhauſted by the crop, it lies fallow every other year, and each acre produces about a ton of barilla *. Whether any of our ſalt marſhes could be advantageouſly employed in this kind of culture, may deſerve the ſerious conſideration of thoſe to whom they belong; certain it is, that plants which would yield this alkali, grow ſpontaneouſly upon ſeveral of them.

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* Kali herbam in cineram verſam *Sódam* appellat vulgus. Baptis. Porta Mag. Nat. L. vi. C. 1. He deſcribes the method of extracting the ſalt out of the aſhes, and ſays that out of five pounds of the aſhes they got one of ſalt.

On the Orkney and Scilly iſles, and on moſt parts of the Britiſh coaſt,

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* Swinburne's Trav. through Spain, p. 130.

coaſt, great quantities of bladder fucus, or ſea oak *, under the name of ſea wrack, are annually burned in order to obtain an alkaline ſalt. The plants are cut from the rocks on which they grow, or gathered from the beach on which they are thrown by the tide; and being ſufficiently dried by the heat of the ſun in the ſummer ſeaſon, they are ſet on fire; the fire-place is a hole in the ground; the aſhes, to which the plants are reduced, are melted by the violence of the fire; the melted maſs is kept in a ſtate of fuſion for three or four hours, it is then ſuffered to cool, and when it is ſet, they take it out of the hole in which the plants were burned, and the operation is recommenced. The ſolid maſs procured from

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* Fucus veſiculoſus, Linnæi.

from the melting of the aſhes of ſea wrack, is an article of great uſe in the making of glaſs and ſoap, and is known in commerce under the name of *kelp*, or *kelp aſhes*. From kelp aſhes may be extracted a ſalt, the ſame in every reſpect with that which may be procured from the aſhes of kali or glaſſwort. The following experiment was made in order to aſcertain the quantity of ſaline matter contained in Britiſh kelp.

Thirty ounces of kelp from the Orknies, which had been previouſly pounded into a fine powder, and in that ſtate well dried upon a hot iron, were boiled in various portions of water, till all the ſaline matter was extracted from the aſhes; the water containing all the ſaline matter of the kelp was then evaporated with a gentle heat, and the ſalt which remained after the water was all evaporated, was further dried, as the kelp had been, upon a hot iron. The ſaline matter in that dry ſtate weighed 19 ounces. The earth remaining after the extraction of the ſaline matter being carefully collected, and thoroughly dried upon a hot iron, it weighed exactly in that ſtate 11 ounces. This experiment was repeated with the ſame ſucceſs.

There is a much greater quantity of ſaline matter contained in Spaniſh barilla than in Engliſh kelp, as may be inferred from the following experiment. Spaniſh barilla, as well as Engliſh kelp, is mixed with ſeveral pieces of black matter; this matter conſiſts of pieces of the plants which have been reduced to charcoal, but not to aſhes, during the combuſtion of the plants. I pounded into a fine powder a quantity of barilla; the powder had a greyiſh caſt from the charcoal it contained; it was dried upon a hot iron, and it loſt by that operation one fourteenth of its weight. I took 30 ounces of this dried barilla, and proceeding as in the analyſis of kelp aſhes, I obtained 22 ounces of ſaline matter. It appears from hence, that there is three hundred weight more of ſaline matter in a ton and an half of barilla, than of kelp aſhes.

It is very probable, that kelp aſhes prepared in different countries, contain the earthy and ſaline parts in proportions different from thoſe here aſcertained; yet it is worth remarking, that the analyſis here given coincides,

cides, as to the earthy part, with the experiments of one author, and as to the ſaline part, with the experiments of another. From 28 drachms of kelp aſhes, Dr. Home obtained 10 drachms of earth; now the proportion of 30 to 11, is nearly the ſame with that of 28 to 10*.—M. Cadet obtained 6 pounds 3 ounces and an half of ſaline matter from 10 pounds of kelp aſhes; if he had obtained one half ounce more, the proportion of ſaline matter procured from the kelp he examined, would have been almoſt exactly the ſame with that procured from the Orkney kelp which I examined †. I was not aware of the experiments here referred to, when I undertook to aſcertain the reſpective quantities of earth and ſaline matter contained in kelp aſhes, and for that reaſon the coincidence may be the better relied on.

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* See his very ingenious Eſſay on Bleaching, p. 151.

† Hiſt. de l' Acad. des Sciences à Par. Ann. 1767, p. 488.

The reader may wonder, why, in ſpeaking of the ſalt contained in kelp, I have called it by the general name, ſaline matter, in the very place where I was conſidering it as a particular kind of ſalt, as an alkali: this was not done without reaſon; for not only kelp aſhes, but the aſhes of kali, barilla, and moſt maritime plants, beſides an alkaline ſalt, contain a portion of common ſalt, and of ſome other kinds of ſalt, which it is not neceſſary here to enumerate. Theſe foreign ſalts injure very much the purity of the alkali, for the obtaining

ing of which the plants are burned; and the Britiſh kelp aſhes abound with them ſo much, that from ſome trials I have made I ſhould conclude, that the 19 ounces of ſaline matter, which I had extracted from 30 ounces of kelp, did not contain above five ounces of pure mineral alkali free from water. The expreſſion, free from water, requires an explanation.

The 19 ounces then of ſaline matter obtained from 30 ounces of kelp, were diſſolved in water, and from the ſolution, when evaporated and cryſtallized, I obtained 12 ounces of alkaline ſalt in very fine tranſparent cryſtals. Since all attraction is mutual, it may readily be underſtood, that as the particles of water attract thoſe of the alkaline ſalt, and retain them in ſolution, ſo the particles of the alkaline ſalt will attract thoſe of the water, and retain them in cryſtallization. The water thus attracted by the particles of a ſalt during its cryſtallization, is uſually denominated the *water of cryſtallization.*

This water of cryſtallization is contained in different quantities in different ſalts, and it adheres to them with different degrees of force; though it is eaſily ſeparated from moſt of them, the moderate heat of the atmoſphere being ſufficient to evaporate it from many. When this water of cryſtallization is evaporated from any ſalt, the figure of the cryſtals is deſtroyed; the ſalt from being a ſolid tranſparent ſubſtance becomes an opake powder. But though a ſalt, in loſing its water of cryſtallization, loſes its cryſtalline form, it does not thereby loſe part of its ſaline quality; for the water which is ſeparated from it is pure water; and the ſalt, by being rediſſolved in water and recryſtallized, will not only regain its former figure, but the whole of its weight.

This obſervation reſpecting the water of cryſtallization is not without its uſe, either in medicine or trade. The ſalt known in medicine under the name of Glauber's ſalt, is one of thoſe which contains near half its weight of water, wholly uneſſential to it as a ſalt: hence an ounce of Glauber's ſalt, in tranſparent cryſtals, has not more ſtrength as a medicine, than half an ounce of the ſame ſalt when reduced to a powder, by having its water of cryſtallization evaporated. The twelve ounces of alkaline ſalt in queſtion were expoſed to a very gentle heat (they would have been melted by a ſtrong one) till they were reduced to a fine powder: this powder was dried on a hot iron, and in that ſtate it weighed not quite five ounces; ſo that twelve tons of alkaline ſalt in cryſtals, is not worth more than five tons of the ſame ſalt, when freed from its water of cryſtallization. Kelp aſhes appear, from theſe experiments, not to contain above five tons of the alkaline ſalt here ſpoken of in thirty tons of the aſhes.

I took the 22 ounces of ſaline matter which I had procured from 30 ounces of dried barilla, and diſſolving them in water obtained 36 ounces of fine cryſtals of alkali, and about 3 ounces of a ſalt which would not cryſtallize,

ſtallize, and which was in part ſea ſalt. It appears from this experiment, compared with the preceding, that the ſalt procurable from barilla, contains a far greater proportion of pure alkali, than that from kelp does; and hence barilla is preferable to kelp, not only from its containing more ſaline matter in a definite weight, but from that ſaline matter being of a purer quality. The cryſtalline ſalt thus obtained, being expoſed to the fire, was quickly melted, and when all the water which had entered into the compoſition of the cryſtals had been evaporated, the ſalt weighed 21½ ounces, half an ounce having been loſt by the operation.

The alkaline ſalt contained in the aſhes of maritime plants, when expoſed to the heat of a glaſs-houſe furnace, loſes conſiderably of its weight, but in moderate fires it loſes nothing; hence this ſalt is called a *fixed alkali*. A pound of common ſalt contains about half a pound of this fixed alkali. Common ſalt is reckoned a mineral, there being large mines of it in moſt parts of the world. This fixed alkali, which conſtitutes near half the weight of common ſalt, and from the decompoſition of which it is moſt probably produced, is therefore often called the *mineral*, *foſſile*, or *marine fixed alkali*. It is entitled alſo to the name of the mineral fixed alkali, from its being met with in ſome mineral waters, and from its being found either ready formed upon the ſurface of the earth, or dug out of certain lakes, which are dried up in the ſummer, in

Egypt, and other parts of the Eaſt. It is there called *natron*, and is ſuppoſed to be the nitre ſpoken of by Solomon, when he compares the effect which unſeaſonable mirth has upon a man in affliction, to the action of vinegar upon nitre; * "as vinegar upon nitre, ſo is he that ſingeth ſongs to a heavy heart:" for vinegar has no effect upon what we call nitre; but upon the alkali in queſtion it has a great effect, making it riſe up in bubbles with much efferveſcence. This alkali has been met with alſo on the Pic of Teneriffe and in Barbary, ſo that it is upon many accounts properly enough denominated the *mineral fixed alkali*.

The aſhes of moſt other vegetables, as well as thoſe of maritime plants, yield a ſalt which has many properties in common with the mineral fixed alkali; but not having all the properties of that ſalt, it has for the ſake of perſpicuity been called the *vegetable fixed alkali.* Both the mineral and the vegetable fixed alkali are prepared by boiling the aſhes, to extract the ſalt from the earth; the water containing the ſalt in ſolution, is then evaporated ſo as to leave the ſalt dry. From this manner of preparing them, theſe ſalts have been often called *lixivial* ſalts, *lix* and *lixivium* both ſignifying a ley made with aſhes. The operation of evaporating the water is performed in large iron or copper pots; and from this circumſtance theſe alkaline ſalts, eſpecially the vegetable fixed alkali, have come under the name of *pot-aſh.*

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* Prov. xxv. 20.

Great piles of wood are, in many countries, burnt for the expreſs purpoſe of obtaining pot-aſh. From the following experiments, ſome notion may be formed of the large quantities of wood which muſt be burned, in order to obtain even a ſmall portion of pot-aſh.

I deſired a friend in Eſſex, who had plenty of dry oak billets, to aſcertain the quantity of aſhes which a certain weight of the wood would yield. He made the experiment with every poſſible precaution, and from 106 pounds, avoirdupois weight, of dry peeled oak, he obtained 19 ounces of aſhes. I treated theſe aſhes after the ſame manner in which I had endeavoured to aſcertain the proportion of earth and ſaline matter in barilla, and kelp aſhes; and from the

19 ounces obtained rather more than one ounce and a quarter of ſaline matter. From ſeveral repetitions of the experiment with aſhes of the ſame kind it may be concluded, that 15 ounces of theſe aſhes contained 14 ounces of earth, not ſoluble in water, and 1 ounce of ſaline matter: from this proportion it may eaſily be collected, that above 1300 tons of dry oak, and probably above 1800 tons of green oak, muſt be burned in order to obtain one ton of pot-aſh.

The makers of pot-aſh generally buy the wood aſhes by the buſhel, and ſell the pot-aſh by the ton; but as the aſhes of different woods, and indeed of different parts of the ſame wood, probably contain very different portions of ſaline matter; it cannot

not be expected that we ſhould have any very uniform accounts of the number of buſhels of aſhes requiſite to make a ton of pot-aſh. Some dealers in this article are of opinion, that a ton of pot-aſh may be procured from 400 buſhels of aſhes; others, from 450; others, from 560 of the beſt aſhes; and others, laſtly, from 700 buſhels, at a medium, of good and bad aſhes*. I find that a buſhel of the dry aſhes which are ſold by the country people who burn wood to our ſoap-makers in Cambridge, weighs at a medium 58 pounds: hence, ſuppoſing every 15 pounds of ſuch aſhes to contain 1 pound of ſaline matter, it will follow, that 580 buſhels of ſuch aſhes would give 1 ton of ſaline matter. This correſpondence with the accounts given by the pot-aſh makers, confirms the analyſis of the oak aſhes before mentioned.

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* Lewis's Experiments on American Pot-aſh, p. 6.

Under the direction and patronage of the Society for the Encouragement of Arts, Manufactures, and Commerce, large quantities of pot-aſh have been made in America ſince the year 1763; and it would be a great ſaving to the nation, if it could be made in ſufficient quantities in any part of the dominions of Great-Britain, ſince we are reckoned to pay to Ruſſia, and other foreign ſtates, not leſs than one hundred and fifty thouſand pounds a-year for pot-aſh *. We have inexhauſtible

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* Doſſie's Mem. of Agricul. Vol. I. p. 248.

hauſtible mines of rock ſalt in this country, which the proprietors can afford at 10 ſhillings a-ton. A ton of rock ſalt, as has been before obſerved of common ſalt, contains about half a ton of mineral alkali, which is for moſt purpoſes far preferable to pot-aſh. If a method could be contrived of extracting this alkaline part from rock ſalt, it would be a moſt ſerviceable diſcovery. To thoſe who have leiſure to attempt it, I would give the following hint—Whether the alkaline part of rock ſalt may not be obtained by calcining it in conjunction with charcoal in open fires? My reaſon for this conjecture is founded on the following experiment: Upon burning ſea wrack to a black coal, and ſtopping the proceſs at that point, I have

I have obtained great plenty of common ſalt, but no mineral alkali from the black aſhes; though we are certain, that when the black aſhes are thoroughly calcined, or reduced to white aſhes, mineral alkali may be obtained from them. This makes it probable, that the common ſalt contained in the black aſhes of ſea wrack, is decompoſed, and changed into a mineral alkali, during the burning of the black aſhes. There are reaſons to ſuppoſe that the cinder of pit-coal would anſwer the purpoſe better than charcoal. But to return.

Tartar is a vegetable production, which forms itſelf on the ſides of caſks in which new wine is put; it is of a ſolid conſiſtency, and is thence called by the Germans, wine-ſtone, (wyne-ſtein): this ſubſtance, when burned to aſhes, yields a very pure vegetable fixed alkali, called, *ſalt of tartar*.

The reader is deſired to diſtinguiſh between *cream of tartar* and *ſalt of tartar*; they are both ſalts, but not of the ſame claſs. Cream of tartar is an *acid*, and is prepared from tartar by diſſolving it in water, and cryſtallizing the ſolution. Salt of tartar is an *alkali*, and is prepared from tartar by burning it, the acid being probably changed into an alkali by the fire.

Salt of tartar, as well as all other vegetable fixed alkalies when pure (for when purified they are all the ſame), attracts very ſtrongly the humidity of the air, and thereby melts as it were into a liquor, which from its being procured in this ſingular way, and from its having alſo an unctuous appearance, tho' it has no other property of an oil, has been called *Oil of tartar per deliquium.* If you ſpread a little ſalt of tartar, or even common pot-aſh on a plate, and expoſe it to the air in a cellar or other moiſt place for a few days, you will ſee the whole of it almoſt melted away into a thick tranſparent liquor, weighing near four times as much as the weight of the ſalt you expoſed. The mineral fixed alkali, expoſed in the ſame way, will not be changed into a fluid; and this is one mark by which the mineral and vegetable fixed alkalies may be diſtinguiſhed from each other. Both of theſe fixed alkalies change the blue colour of ſyrop of violets into a green, and by this property they are diſtinguiſhable from acids, which give a red colour, as well as by their taſte, which is cauſtic and fiery, every way very different from a ſour taſte. They bubble up alſo or efferveſce when mixed with acids, as may be ſeen by mixing lemon-juice and ſalt of tartar together. This efferveſcence proceeds from the diſcharge of an elaſtic fluid, called *fixed air*, but it cannot be ſaid to be characteriſtic of alkalies; ſince chalk, marble, limeſtone, and other earths and ſtones not ſoluble in water, contain a large portion of *fixed air*, and, when mixed with acids, efferveſce as much as fixed alkalies. From this property, theſe earthy and ſtony ſubſtances have, in many ſyſtems of mineralogy, been called *alkaline* earths and ſtones.

Beſides the fixed alkaline ſalts ſeparable from the aſhes of maritime plants, and other vegetable ſubſtances, there is another ſpecies of ſalt ſeparable chiefly from animal ſubſtances, as from urine, horns, bones, &c. by diſtillation. This ſalt efferveſces with acids, and gives a green colour to vegetable blues, and it is from hence called an alkali; but being eaſily diſſipated in a ſmall degree of heat, it is called a *volatile alkali*. By this great volatility it is ſufficiently diſtinguiſhed from the two fixed alkalies, as well as by the pungency of its ſmell; fixed alkalies, when pure, having no ſmell.

Of neutral ſalts.

Neutral ſalts are diſtinguiſhed both from acids and alkalies by their taſte, which is neither ſour nor cauſtic, by their not effervescing with acids, by their not producing any change in the colour of ſyrop of violets. Of this kind are common ſalt, Glauber's ſalt, ſaltpetre, and a great variety of others. Any acid, when united with any alkali in ſuch proportion that the compound does not poſſeſs any of the characteriſtic properties of either of its component parts, is a neutral ſalt. The term neutral, was firſt applied to a ſalt formed by an union of an acid and an alkali; but it has now a more extenſive ſignification, denoting the ſalt formed by the union of an acid with any alkali, earth, or metallic ſubſtance. The ſubſtance with which the acid unites itſelf in the formation of a neutral ſalt, is often called the *baſis* of that ſalt.

The following tables of ſalts will help to fix in the reader's mind the general diviſion of ſaline ſubſtances, eſpecially if he will be at the trouble to familiarize himſelf to the names, by procuring from his druggiſt ſpecimens of the ſeveral kinds.

A Table of Salts in general.

Salts.	Acid	Mineral	Vitriolic Acid—Spirit of Vitriol—Oil of Vitriol		
			Nitrous Acid—Aqua Fortis—Glauber's fuming Acid of Nitre		
			Marine Acid—Muriatic Acid—Glauber's fuming Acid of Salt		
		Vegetable	Native	Juices of Lemons and other Acid Vegetables	
			Factitious by	Fermentation	Acetous Acid, or Vinegar
					Tartareous Acid, or Tartar
				Diſtillation	Not ſpecifically known
		Animal	Phoſphoric Acid		
			From Ants, Butter, &c. by Diſtillation		
	Alkaline	Fixed	Mineral—Foſſile—Marine—Natron		
			Vegetable—Potaſh—Salt of Tartar—Salt of Wormwood		
		Volatile	Obtained by Diſtillation from putrid Blood, Urine, Bones, Horns and other animal Subſtances; and alſo from Wormwood and many other, both Vegetables and Minerals, when diſtilled with a violent Fire.		
	Neutral	From the Union of any Acid with any	Alkali		
			Earth		
			Metallic Subſtance		

A Table of neutral Salts, with Alkaline Bafes.

Acid.			
Vitriolic with	Mineral	Alkali makes	Glauber's Salt
	Vegetable		Vitriolated Tartar
	Volatile		Vitriolic Sal Ammoniac
Nitrous with	Mineral	Alkali makes	Cubic Nitre
	Vegetable		Common Nitre or Saltpetre
	Volatile		Ammoniac Nitre
Marine with	Mineral	Alkali makes	Common Salt
	Vegetable		Digeſtive Salt of Sylvius
	Volatile		Common Sal Ammoniac
Acetous with	Mineral	Alkali makes	A cryſtallizable Salt, not yet named
	Vegetable		Diuretic Salt, improperly called Terra fol. Tar.
	Volatile		Spirit of Mindererus
Tartareous * with	Mineral	Alkali makes	Rochelle Salt
	Vegetable		Soluble Tartar
	Volatile		Soluble Ammoniac Tartar

* In this general account, I purpoſely omit the mention of the lately diſcovered Sparry Acid; of the Acid of Amber; of the Acid of Benjamin, and other Bitumens; and of ſome other particularities relative to this ſubject.

It may not be improper, in this place, to mention two propoſitions much inſiſted on by chemical writers of the greateſt eminence, but which appear to be founded rather on probable conjecture than certain experiment. The firſt is, that the *vitriolic acid* is the only ſaline principle in nature, all other acids and alkalies being nothing but combinations of this *univerſal acid* with earth, air, oil, and water, in different proportions. The ſecond is, that the vitriolic acid itſelf is a compound body, formed from an intimate union of *earth* and *water.* The poſſibility of the truth of the firſt propoſition, which aſſerts, that one ſubſtance may be ſo combined with ſeveral others as to conſtitute a great variety of different compounds, may be illuſtrated from what we know of water; which is the chief conſtituent part of bodies in appearance very different from each other, as of blood, urine, milk, wine, wood, coal, &c. yet the *marine acid* ſeems to be as abundantly diffuſed over the earth as the vitriolic; and cannot, I think, be ſaid to be derived from it. As to the ſecond propoſition, though we ſhould grant that nothing but earth and water can be procured from the analyſis of any ſalt, (which, conſidering the loſs ſuſtained almoſt in every analyſis from the eſcape of ſome elaſtic fluid which cannot be condenſed, cannot readily be admitted;) yet as no one could ever form a ſaline ſubſtance by uniting earth and water together, we may fairly doubt concerning its truth: this doubt, however, is not to be underſtood as a denial. The ſum of the matter is this: earth and water cannot be formed by us into ſaline ſubſtances: nature *may* have different modes of combining them, ſo as to produce the effect; or nature *may*, in producing the effect, make uſe of a third or a fourth principle. It muſt be left to future experience to ſimplify our knowledge concerning ſaline ſubſtances, as well as concerning thoſe fluids which produce magnetiſm and electricity, and all the various phenomena attending mineral exhalations.

ESSAY IV.

Of Fire, Sulphur, and Phlogiſton.

FIRE is ſo ſubtile an agent in nature, that we can reaſon little concerning it, except from experiment; and we are even at a loſs from thence to determine, in many caſes, either its abſolute quantity or real preſence. If, with the generality of philoſophers, we aſſume heat as its characteriſtic property, and define fire to be that which warms or heats bodies, we cannot avoid ſeeing at once, the ambiguity of this criterion: it is as precarious as the perceptions of different men at the ſame time, or of the ſame man at different times, in ſummer and in winter, in a fever and in health. The light of the moon, when collected into the focus of a large burning-glaſs, is found to be about one thouſand times leſs denſe than the direct rays of the ſun: hence it is, that it excites no motion in the mercury of the moſt ſenſible thermometer. But from the brightneſs of the image in the focus, as well as from the luminous appearance of rotten wood, putrid fiſh, and other phoſphoreſcent bodies, ſome philoſophers have inferred, that wherever there is light there is fire: but as the converſe of this propoſition is not true, ſince fire often exiſts in large quantities, as in boiling fluids, in metals moderately heated, &c. without light; this cannot be a diſtinguiſhing mark of the preſence of fire. The dilatation which fire occaſions in all bodies, whether ſolid or fluid, hard or ſoft, light or heavy, may be eſteemed the moſt certain proof of its preſence and agency. This property ſerves admirably to mark its degrees and minute variations within certain limits, but not to aſcertain either its preſence or its quantity in extreme caſes, unleſs we know the real magnitudes of bodies totally deſtitute of it. However, admitting this phenomenon as the moſt certain indication of the exiſtence of fire, it may be accounted for in the following manner.

From the 14th ſection of Sir *Iſaac Newton*'s *Principia*, we learn, that the motions of ſmall bodies, when attracted perpendicularly towards any ſurface, according to any law, are ſimilar to the motions of the rays of light, with reſpect to the fundamental properties of Inflection, Reflection, and Refraction: from hence chiefly, as well as from other arguments, we infer, that rays of light are ſmall corpuſcles, emitted from ſhining bodies, and moving with uniform velocities in uniform mediums; but with variable velocities in mediums of variable denſities. This being admitted, it will follow, that in whatever quantity the rays of light are made to move in a medium of an uniform denſity, they will not agitate the particles, or produce any augmentation of bulk in that medium. If the atmoſphere was reduced to a medium of an uniform denſity, ſurrounding the earth every where to the height of five miles, it would be expanded in bulk, or warmed only as its outward and inward ſurface. The ſun's rays, by coming out of a *vacuum* into a denſer medium, would be attracted by the particles compoſing that medium; and, ſince all attraction is mutual, they would excite a motion, an expanſion, an heat, at the outward ſurface where they entered: from thence they would proceed uniformly; without producing any effect, till they came to the inward ſurface of the atmoſphere contiguous to the ſurface of the earth, where they would undergo another acceleration of velocity, and would excite another degree of motion, another degree of expanſion or heat. Such an atmoſphere would be the coldeſt in the middle, the heat decreaſing from each ſurface. We may, perhaps, from what has been ſaid, conceive, in ſome meaſure, how bodies are expanded, heated, and volatilized, by the agency of the particles of light. Theſe particles act upon the minute conſtituent parts of bodies, not by impact, but at ſome indefinitely ſmall diſtance; they attract, and are attracted; and in being reflected, or refracted, they excite a vibratory motion in the component particles. This motion increaſes the diſtance between the particles; an increaſe of the diſtance between the conſtituent parts of any body, is an augmentation of bulk, an expanſion in every dimenſion,

ſion,—the moſt certain characteriſtic of fire. This expanſion, which is the beginning of a diſunion of the parts, being increaſed by the increaſing magnitude of the vibrations proceeding from the continued agency of the light, it may eaſily be apprehended, that the particles will at length vibrate beyond their ſphere of mutual attraction, and thus the texture of the body will be altered or deſtroyed : from ſolid it may become fluid, as in melted gold ; or from being fluid, it may be diſperſed in vapour, as in boiling water.

According to this theory, we muſt infer, that the conſtituent parts of all bodies are in perpetual motion. The temperature of the atmoſphere is different in different latitudes, and it changes, almoſt every inſtant, in the ſame. The temperature of bodies is ever proportionable to that of the ſurrounding atmoſphere, and from thence it muſt be perpetually varying. The bulk of every body is proportionable to its temperature, and muſt therefore be ſubject to a perpetual viciſſitude. Now the body will be in an expanded, in the next inſtant, its heat happening to be diminiſhed, it will be in a contracted ſtate; which variation of dimenſions cannot be effected without a perpetual vibratory motion of its conſtituent parts.

It being eſtabliſhed then, that the rays of the ſun, even in their moſt condenſed ſtate, as in the focus of a burning ſpeculum, do not otherwiſe produce heat than as they excite a motion more or leſs violent amongſt the conſtituent parts of bodies; and the effects of culinary fire, of that produced by friction, or by the impact of hard bodies, being ſimilar to thoſe produced by the agency of the ſun's light, it may be conjectured, that they are produced after a ſimilar manner; and that fire is nothing diſtinct from the parts of bodies put into motion by various cauſes, as the impulſe of light, friction, percuſſion, putrefaction, attraction of coheſion, &c. and conſequently that it may be mechanically produced, altered, or deſtroyed in all bodies, with greater or leſs facility, according as the parts of the body are more or leſs diſpoſed for motion.

This concluſion ſeems to be conſonant with the principles of the received philoſophy. Newton in his 5th quære annexed to his Optics, aſks, Do not bodies and light act mutually upon one another? that is to ſay, bodies upon light in emitting, reflecting, refracting, and inflecting it; light upon bodies for heating them, and putting their parts into a vibratory motion, wherein heat conſiſts?

There are various other opinions concerning the nature of fire and its method of action, which, though different from what has been offered, are not leſs probable: I will content myſelf with mentioning two more.

Boerhaave thinks that fire is a fluid of a nature peculiar to itſelf; that it was created ſuch as it is, and cannot be altered in its nature or properties, deſtroyed or produced; that it naturally exiſts in equal quantities in all places; that it is wholly imperceptible to our ſenſes, and only diſcoverable by ſuch effects as it produces, when, by various cauſes, it is for a time collected into a leſs ſpace than what, from its tendency to an univerſal and equable diffuſion, it would otherwiſe occupy. All the bodies which are ſituated in the immenſity of ſpace, may, according to this opinion, be divided into fire expanding all other bodies, and into all the other bodies which are not fire, but reſiſt its action. The matter of this fire is not ſuppoſed to be derived from the ſun in any wiſe; the ſolar rays, whether direct or reflected, are of uſe only as they impel the particles of fire in parallel directions: that paralleliſm being deſtroyed, by intercepting the ſolar rays, the fire inſtantly reſumes its natural ſtate of uniform diffuſion*. Conſiſtent with this explication, which attributes heat to the matter of fire, when driven in parallel directions, a much greater

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[*] Poſſent omnia corpora locata in ſpatio immenſo dividi, in ignem expandentem omnia reliqua corpora, et in cætera univerſa corpora quæ non ſunt ignis —— Ignem illum ſemper eſſe ubique præſentem, tam in pleno corporeo pleniſſimo quam in vacuo inaniſſimo —— Ignem hunc æquabiliſſime diſtribui tamdiu, quamdiu non naſcitur cauſa ſingularis in loco certo ignem hunc diſperſum colligens —— Ignem hunc non eſſe a ſole, quoad materiam ullo modo — Vim ignis a ſole determinatam in rectas parallelas remanere in omni tempore, quo emanatio vel reflexio durat —— intercepta rectitudine radiorum a ſole, ignem in paralleliſmum agentium, illico ceſſat ille paralleliſmus, atque ſtatim illo ipſo momento ignis partes expanduntur æquabiliter quaquaverſum. — Boerh. Chem. Vol. 1.

greater muſt be given it, when the quantity ſo collected, is amaſſed into a focus; and yet the focus of the largeſt ſpeculum does not heat the air, or medium in which it is formed, but only bodies of denſities different from that medium.

The author of the *Lettres Phyſiques* is of opinion, that the ſolar rays are the principal cauſe of heat; but that they only heat ſuch bodies as do not allow them a free paſſage*. In this remark he is agreed with Newton †; but then he differs totally from him, as well as from Boerhaave, concerning the nature of the rays of the ſun. He does not admit the emanation of any luminous corpuſcles from the ſun, or other ſelf-ſhining ſubſtances, but ſuppoſes all ſpace to be filled with an æther of great elaſticity and ſmall denſity, and that light conſiſts in the vibrations of this æther, as ſound conſiſts in the vibrations of the air; the particles of the one medium exciting, by impulſe upon the organ of viſion, the idea we call light; the particles of the other medium exciting, by impulſe on the organ of hearing, the idea we call ſound *. But as a bell will not of itſelf begin thoſe

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* Les rayons du ſoleil n'echauffent les corps qu' entant que les corps ne leur accordent un libre paſſage à travers. Lett. Phys.

† Radii ſolis non agitant media quæ permanant, niſi in reflexione et refractione. New.

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* La lumiere n'eſt autre choſe qu'une agitation ou ebranlement cauſé dans les particules de l'ether qui ſe trouve partout.—— Il n'y a donc rien qui vienne actuellement du ſoleil juſque à nous. Let. Phy.

thoſe vibrations by which the air is put in motion, nor continue with equal intenſity the vibrations, when once excited, without the concurrence of ſome mechanical cauſe; ſo neither will the ſun either begin or continue his vibrations, by which the ſuppoſed æther is put in motion, without a ſimilar mechanical agency. In aſcending from effects to cauſes we muſt ever arrive, upon whatever hypotheſis we proceed, at ſome firſt cauſe, which does not admit an explanation from mechanical principles: this is evidently the caſe in the preſent inquiry. Upon Newton's ſuppoſition, the cauſe by which the particles of light, and the corpuſcles conſtituting other bodies, are mutually attracted and repelled, is uncertain. The reaſon of the uniform diffuſion of fire, of its vibration, and repercuſſion, as ſtated in Boerhaave's opinion, is equally inexplicable; and in the laſt mentioned hypotheſis, we may add to the other difficulties attending the ſuppoſition of an univerſal æther, the want of a firſt mover to make the ſun vibrate. Theſe are the opinions moſt worthy of notice, concerning elementary fire; and of theſe it may be ſaid, as Cicero remarked of the opinions of philoſophers concerning the nature of the ſoul,—*harum ſententiarum quæ vera ſit, Deus aliquis viderit, quæ veriſimillima, magna queſtio eſt* *.

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* The reader who is deſirous of making a deeper inquiry into this matter, may conſult a very ingenious tract entitled, Experiments and Obſervations on animal Heat, and the Inflammation of combuſtible Bodies, by Dr. Crawford;

But beſides this *elementary fire*, which chemiſts conceive to be every where uniformly diffuſed, they are of opinion that fire enters, in different proportions, into the compoſition of all vegetables and animals, and moſt minerals; and in that condenſed, compacted, fixed ſtate, it has been

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Crawford; and Mr. Scheele's Experiments on Air and Fire, tranſlated from the German by Dr. Forſter, and illuſtrated with judicious notes by Mr. Kirwan; and a late work of Wallerius', entitled Meditationes de Orig. Mund.

May not the common degree of *heat* which ariſes from the mixture of different quantities of the ſame fluid heated to different degrees, be inveſtigated by the ſame rule, by which the common *velocity* of hard or non-elaſtic bodies after their impact in the ſame direction is calculated, putting the *momentum* of heat to be equal to its degree multiplied into the quantity of heated matter?

been denominated the *phlogiſton.* Of itſelf, in its natural ſtate of uncombined expanſion, fire is not eſteemed capable of ſhining, or burning; when chemically conjoined with the other principles of bodies, it is that alone which conceives and continues thoſe motions by which bodies are made to ſhine, to burn, to conſume away. All bodies are more or leſs ſuſceptible of combuſtion, according to the quantity of this principle which enters into their compoſition, or the degree of force with which it adheres to them. In the act of burning, and it may very probably be during the fermentation, and putrefaction, and chemical ſolutions of various bodies, it recovers its fluidity, is expanded and diſperſed into the air, or combined anew with ſuch ſubſtances as it has an attraction to. Notwithſtanding all that perhaps can be ſaid upon the ſubject, I am ſenſible the reader will be ſtill ready to aſk—*what is phlogiſton?* You do not ſurely expect that chemiſtry ſhould be able to preſent you with a handful of phlogiſton, ſeparated from an inflammable body; you may juſt as reaſonably demand a handful of magnetiſm, gravity, or electricity to be extracted from a magnetic, weighty, or electric body. There are powers in nature which cannot otherwiſe become the objects of ſenſe, than by the effects they produce; and of this kind is phlogiſton. But the following experiments will tend to render this perplexed ſubject ſomewhat more clear.

If you take a piece of *ſulphur,*

and ſet it on fire, it will burn intirely away, without leaving any aſhes, or yielding any ſoot. During the burning of the ſulphur, a copious vapour, powerfully affecting the organs of ſight and ſmell, and the action of the lungs, is diſperſed. Means have been invented for collecting this vapour, and it is found to be a very ſtrong acid. The acid thus procured from the burning of ſulphur, is incapable of being either burned by itſelf, or of contributing towards the ſupport of fire in other bodies: the ſulphur from which it was procured was capable of both: there is a remarkable difference then, between the acid procured from the ſulphur, and the ſulphur itſelf. The acid cannot be the only conſtituent part of ſulphur; it is evident that *ſomething* elſe muſt have entered into its compoſition, by which it was rendered capable of combuſtion. This *ſomething* is, from its moſt remarkable property, that of rendering a body combuſtible, properly enough denominated the food of fire, the *inflammable principle*, the *phlogiſton*.

From this analyſis we may conclude, that the conſtituent parts of *ſulphur* are two; — an *inflammable principle*, which is diſperſed in the act of combuſtion, and an *acid*. The proportion of theſe parts has been aſcertained; and it is found, that in any maſs of ſulphur, the weight of the inflammable principle is to that of the acid in the proportion of 3 to 50 *.

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* The experiment from which this proportion is derived, is ſaid to have been made by

If you burn *charcoal* in the open air, and hold a glaſs over its flame, you will perceive that it burns without emitting either any watery vapour or ſooty impurity; and nothing will remain, from a large portion of charcoal, but a ſmall portion of white aſhes, which are incapable of any further combuſtion. The principle effecting the combuſtion of the charcoal, and diſperſed by the act of combuſtion, is the phlogiſton.

If you ſet *ſpirits of wine* on fire, they will, if pure, burn intirely away: they differ from charcoal in this,

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by M. Brandt with great accuracy about the year 1756. Spielm Chem. p. 111. and Chem. Dict.—Newman from a ſimilar experiment infers, that in 16 ounces of ſulphur, there are upwards of 15¾ ounces of pure acid, and not quite ¼ of an ounce of the inflammable principle. Newm. Chem. p. 168

this, that they emit a vapour; but they leave no reſiduum. You may by proper veſſels collect the vapour of burning ſpirits, and you will find it to be an inſipid water, incapable of combuſtion. The principle effecting the combuſtion of the ſpirits of wine, and diſperſed by the act of combuſtion, is the phlogiſton.

Some *metallic ſubſtances* burn, when ſufficiently heated, with a flame more bright than that of ſpirits of wine, or charcoal; others burn or ſmother away like rotten wood; and moſt of them, when they have been kept in the open air in a proper degree of heat, loſe their metallic appearance, and are converted into earth. Thus *red lead* is the earth procured from the burning of lead; and *putty*, ſuch as the poliſhers of glaſs and marble uſe, is the earth procured from tin. The principle effecting the combuſtion of metallic ſubſtances, and diſperſed in the act of combuſtion, is the phlogiſton.

The *acid of the ſulphur* ; the *aſhes of the charcoal*; the *water of the ſpirits of wine*; the *earths of metallic ſubſtances*, are utterly incapable of combuſtion: their reſpective differences from ſulphur, charcoal, ſpirits of wine, and metallic ſubſtances, with reſpect not only to inflammability, but to ſmell, colour, conſiſtency, and other properties, are attributed to the phlogiſton which is diſperſed during the combuſtion of each of them.

This inflammable principle, or phlogiſton, is not one thing in animals, another in vegetables, another in minerals, it is abſolutely the ſame in them all; juſt as water which enters into the compoſition of fleſh, wood, coal, is ſtill water, though its exiſtence and homogeneity be rendered more doubtful in ſome ſubſtances than in others. This identity of phlogiſton may be proved from a variety of deciſive experiments; I will ſelect a few, which may at the ſame time confirm what has been advanced concerning the conſtituent parts of ſulphur.

From the analyſis or decompoſition of ſulphur effected by burning, we have concluded, that the conſtituent parts of ſulphur are two, — an *acid* which may be collected, and an *inflammable principle* which is diſperſed. If the reader has yet acquired any real taſte for chemical truths, he will wiſh to ſee this analyſis confirmed by ſyntheſis ; that is, in common language, he will wiſh to ſee ſulphur actually made, by combining its acid with an inflammable principle. It ſeldom happens that chemiſts can reproduce the original bodies, though they combine together all the principles into which they have analyſed them ; becauſe not only the number and proportions of the principles, but the order alſo of their arrangement muſt be obſerved, before that can be effected : in the inſtance, however, before us, the reproduction of the original ſubſtance will be found complete.

As the inflammable principle cannot be obtained in a palpable form ſeparate from all other bodies, the only method by which we can attempttempt to unite it with the acid of ſulphur, muſt be by preſenting to that acid ſome ſubſtance in which it is contained. Charcoal is ſuch a ſubſtance, and by diſtilling powdered charcoal and the acid of ſulphur together, we can procure a true yellow ſulphur, in no wiſe to be diſtinguiſhed from common ſulphur. This ſulphur is formed from the union of the acid with the phlogiſton of the charcoal; and the charcoal may by this means be ſo entirely robbed of its phlogiſton, that it will be reduced to aſhes, as if it had been burned. Animal ſubſtances reduced to the ſtate of a black coal, will, by being treated in the ſame way, yield ſulphur.

Spirits of wine, we have ſaid, conſiſt of phlogiſton united with water;

and if we diſtil a mixture of ſpirits of wine and the acid of ſulphur, we ſhall towards the end of the operation obtain a pure ſulphur.

Oil of turpentine is very inflammable, and conſequently abounds with the principle which has been denominated phlogiſton; and from a diſtillation of acid of ſulphur with oil of turpentine, a ſulphur may be procured.

But one of the ſhorteſt and moſt obvious ways of illuſtrating both the compoſition of ſulphur and the phlogiſton of metallic ſubſtances, is the following.—Upon melted lead pour the acid of ſulphur; collect the vapour which will ariſe, by holding a very large glaſs or other veſſel over the melted lead, and you will, as ſoon as the vapour is condenſed, obſerve ſeveral filaments of ſulphur ſticking to the ſides of the glaſs.—When lead is in a ſtate of ſtrong fuſion, its phlogiſton is in a ſtate of diſperſion; the acid of ſulphur inſtantaneouſly unites itſelf with this phlogiſton, and forms ſulphur. It is probable, that ſulphur might be procured by the ſame means from a variety of other bodies, when in a ſtate of actual combuſtion.

I will in this place, by way of further illuſtration of the term phlogiſton, add a word or two concerning the neceſſity of its union with a metallic earth, in order to conſtitute a metal.

Lead, it has been obſerved, when melted in a ſtrong fire, burns away like rotten wood; all its properties as a metal are deſtroyed, and it is reduced to aſhes. If you expoſe the aſhes of lead to a ſtrong fire, they will melt; but the melted ſubſtance will not be a *metal*; it will be a yellow or orange-coloured *glaſs*. If you pound this glaſs and mix it with charcoal duſt, or if you mix the aſhes of the lead with charcoal duſt, and expoſe either mixture to a melting heat, you will obtain, not a *glaſs*, but a *metal*, in weight, colour, conſiſtency, and every other property the ſame as lead. This operation by which a metallic earth is reſtored to its metallic form, is called *Reduction*. The aſhes of lead melted *without* charcoal become *glaſs*; the aſhes of lead melted *with* charcoal become a *metal*; the charcoal then muſt have communicated *ſomething* to the aſhes of lead, by which they are changed from a glaſs to a metal. Charcoal conſiſts but of two things, of aſhes, and of *phlogiſton*; the *aſhes* of charcoal, though united with the aſhes of lead, would only produce glaſs; it muſt therefore be the other conſtituent part of charcoal, or phlogiſton, which is communicated to the aſhes of lead, and by an union with which the aſhes are reſtored to their metallic form. The aſhes of lead can never be reduced to their metallic form, without their being united with ſome matter containing phlogiſton; and they may be reduced to their metallic form, by being united with *any* ſubſtance containing phlogiſton in a proper ſtate, whether that ſubſtance be derived from the animal, vegetable, or mineral kingdom; (for tallow or iron filings may be ſubſtituted with ſucceſs in the room of charcoal, in the experiment of reducing the aſhes of lead) and thence we conclude, not only that phlogiſton is a neceſſary part of a metal, but that phlogiſton has an identity belonging to it, from whatever ſubſtance in nature it be extracted. And this aſſertion ſtill becomes more general, if we may believe that metallic aſhes have been reduced to their metallic form, both by the ſolar rays and the electrical fire.

ESSAY V.

Of the Origin of Subterraneous Fires.

THE moſt remarkable changes which have taken place in the form and conſtitution of the earth, ſince the deluge, have probably been produced by ſubterraneous fires; for it is to their agency that philoſophers aſcribe volcanos and earthquakes; thoſe tremendous inſtruments of nature, by which ſhe converts plains into mountains, the ocean into iſlands, and dry land into ſtagnant pools.

Dr. Hooke formerly had maintained that all land had been raiſed out of the ſea by earthquakes; and modern philoſophers ſeem to admit his hypotheſis, though not, perhaps, in its utmoſt latitude. Thus one of them is of opinion, that *Iceland*, which is bigger than *Ireland*, has been produced by volcanos in the courſe of ſeveral centuries*. Another, after giving an ingenious conjecture concerning the origin of all the *tropical low iſles* in the South Sea, aſſures us, that of the *higher iſles* there is hardly one of them which has not ſtrong veſtiges of its having undergone ſome violent alteration by a volcano. Some of them have volcanos ſtill ſubſiſting; others, amongſt which are *O-Taheitee* and *Huaheine*, ſeem to have been elevated, in remote ages, from the bottom of the ſea by ſubterraneous fires *.

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* See Letters on *Iceland* by Dr. Uno Von Troil, p. 222.

When theſe fires were firſt kindled; by what ſort of fuel they are ſtill maintained; at what depths below the ſurface of the earth they are placed; whether they have a mutual communication; of what dimenſions they conſiſt; and how long they may continue, are queſtions which do not admit an eaſy deciſion. The ſurface of the earth is admirably fitted for the ſupport of the exiſtence and well-being of all the animals which

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* Obſervations made during a Voyage round the World by Dr. Forſter, p. 151; where the reader will find in a note, a learned reference to the works of a great many authors, on the ſubject of iſles raiſed out of the ſea by the action of a ſubterraneous fire.

inhabit it. God has given *us* the ability alſo to penetrate a very little below this ſurface; and as the reward of our induſtry, he has placed within our reach a great variety of uſeful minerals; but as to the central receſſes of the globe, we can never penetrate into them. A gnat eſſaying the feeble efforts of its ſlender proboſcis againſt the hide of an elephant, and attempting thereby to inveſtigate the internal formation of the body of that huge animal, is no unapt repreſentation of man attempting to explore the internal ſtructure of the earth, by digging little holes upon its ſurface.

But though it will ever be impoſſible for us to ſearch far into the bowels of the earth, or to imitate, in an extenſive degree, the great operations

rations which are conſtantly carrying on beneath its ſurface, yet it affords a curious mind no mean degree of ſatisfaction to be able, by obvious experiments, to form ſome reaſonable conjectures concerning them.

Mr. Lemery *, as far as I have been able to learn, was the firſt perſon who illuſtrated, by actual experiment, the origin of ſubterraneous fires. He mixed twenty-five pounds of *powdered ſulphur* with an equal weight of *iron filings*; and having kneaded the mixture together, by means of a little *water*, into the conſiſtence of a paſte, he put it into an iron pot, covered it with a cloth, and buried the whole a foot under ground. In about eight or nine hours time the earth ſwelled, grew warm, and cracked; hot ſulphureous vapours were perceived; a flame which dilated the cracks was obſerved; the ſuperincumbent earth was covered with a yellow and black powder: in ſhort, a ſubterraneous fire, producing a volcano in miniature, was ſpontaneouſly lighted up from the reciprocal actions of ſulphur, iron, and water.

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* Cours de Chemie, p. 176. & Mem. de l' Acad. des Scien. a Paris, Ann. 1700.

That part of this experiment which relates to the production of fire, by the fermentation of iron filings and ſulphur when made into a paſte *, has been frequently repeated

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* The words *ferment* and *fermentation* may perhaps be improperly applied to the ſpontaneous tranſpoſition of parts, which takes place in *mineral ſubſtances*; but the reader cannot fail to underſtand what is meant by them when thus applied.

peated ſince the time of Mr. Lemery. I myſelf have made it more than once, but I have nothing material to add to his account, except that the flame, when the experiment is made in the open air, is of very ſhort duration; and that the whole maſs, after the extinction of the flame, continues at intervals, for a longer or ſhorter time, according to its quantity, to throw out ſparks; and that a ladle full of the ignited maſs, being dropped down from a conſiderable height, deſcends like a ſhower of red-hot aſhes, much reſembling the paintings of the eruptions of Mount Veſuvius which may be ſeen at the Britiſh Muſeum. It has been obſerved, that large quantities of the materials are not requiſite to make the experiment ſucceed, provided there be a due proportion of water: half a pound of ſteel filings, half a pound of flowers of brimſtone, and fourteen ounces of water, will, when well mixed, acquire heat enough to make the maſs take fire *.

That heat and fire ſhould be generated from the ſpontaneous actions of *minerals* upon each other, is a phenomenon by no means ſingular in nature, how difficult ſoever it may be to account for it. The heat of putreſcent dunghills, of the fermenting juices of vegetables, and, above all, the ſpontaneous firing of hay not properly dried, are obvious proofs that *vegetables* poſſeſs this property as well as minerals. In both vegetables and minerals, a definite quantity of moiſture is requiſite to enable them to commence that inteſtine motion of their parts, which is neceſſary for the production of fire. Iron and ſulphur would remain mixed together for ages without taking fire, if they were either kept perfectly free from moiſture, or drenched with too much water; and vegetables in like manner, which are quite dry, or exceedingly wet, are incapable of taking fire whilſt they continue in that ſtate*.

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* Sage Miner. Vol. I. p. 42.

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* *Animal* ſubſtances when laid on heaps, have been obſerved to take fire. " M. Montet rapporte dans l' hiſtoire de l' Académie Royale des Sciences, année 1776, que des petites étoffes appellés *imperiales*, gardées en tas, prirent feu d' elles-memes." Inſtruc. ſur l' uſage de la Houille par M. Venel. It is not improbable that filings of copper and other

But though it is certain from the experiment, that mixtures of iron and ſulphur, when moiſtened with a proper quantity of water, will ſpontaneouſly take fire; yet the origin of ſubterraneous fires cannot, with any great degree of probability, be referred to the ſame principle, unleſs it can be ſhewn that nature has combined together in large quantities iron and ſulphur, and diſtributed the compoſition through various internal parts of the earth.

Now that this is really the caſe we can have no doubt. There is, perhaps, no mineral more commonly met

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other metals, when mixed in a due proportion with ſulphur and water, would acquire a heat, and perhaps take fire, eſpecially if the quantities were large; but experiments of this kind have not hitherto been made.

met with than that which is compoſed of iron and ſulphur. It is found not only upon the ſurface of the earth, but at the greateſt depths below it, to which mines have been hitherto driven; not only in England or Italy, Europe or Aſia, but in all parts of the world. This mineral is called in ſome parts of England, *copperas-ſtone*; in others, *brazil*; in others, *braſs-lumps*; in others, *ruſt-balls*; in others, *horſe-gold*; in others, *marcaſite*; though naturaliſts are now, I think, agreed to give that name to ſuch mineral bodies as are angular and cryſtallized, eſpecially into a cubical form. The ſcientific name is *Pyrites*,—*fiery*; a denomination expreſſive enough of the property which this mineral has of ſtriking fire with ſteel, and of ſpontaneouſly taking fire, when laid in heaps, and moiſtened with water.

Sulphur and iron are the chief conſtituent parts of the pyrites; arſenic, however, is ſometimes united with the iron inſtead of ſulphur, and ſometimes ſulphur and arſenic are both of them combined with iron. The pyrites alſo, accidentally, contains copper, ſilver, and perhaps gold: hence the pyrites has been diſtinguiſhed by mineralogiſts into various ſorts, by attending, either to its internal conſtitution, as the iron, the copper, the ſulphureous, the arſenical pyrites; or to its external figure, as the pyramidal, the cubical, the ſpherical, the priſmatic pyrites;

or to its colour, as the grey, white, yellowiſh, yellow, orange pyrites *.

Though the reader may have never contemplated the various ſpecies of the pyrites in any cabinet of natural hiſtory, or taken notice of ſuch kinds as are commonly to be met with in chalk-pits, in beds of clay, or upon the ſea ſhore in many places of England, yet the yellowiſh matter, often adhering to, or mixed with the ſubſtance of pit-coal, cannot, ſurely, have eſcaped his obſervation: that matter conſiſts of *ſulphur* and *iron*, and is a ſpecies of the pyrites. So much of this ſort of the pyrites is dug up together with the coal, at Whitehaven, Newcaſtle, and other places, that people are employed to pick it out from amongſt the coal, leſt it ſhould vitiate its quality, and render it leſs ſaleable. The pieces of the pyrites which are ſeparated from the coal, are not thrown aſide as uſeleſs, but laid in heaps, for a purpoſe to be mentioned hereafter; and theſe heaps, not many years ſince, *took fire* both at *Whitehaven* and in the neighbourhood of *Halifax*. The ſame accident was obſerved above a hundred years ago at *Puddle Wharf* in London, where heaps of coal which contained much of this pyrites *took fire* *.

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* Whoever wiſhes to become fully acquainted with the natural hiſtory of the pyrites, may conſult the *Pyritologia* of Henckel, where he will find the origin, nature, and uſes of this mineral inveſtigated with the greateſt learning and ingenuity.

Though Lemery was the firſt

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* Jorden of Miner. Wat. C. xiv.

perſon who, by artificial mixtures of ſulphur and iron, produced fire, yet that natural mixtures of theſe ſubſtances would *ſpontaneouſly take fire*, was known before he made his experiment. Thus, to omit what is ſaid by Pliny and the ancients, we are told by good authority, that one Wilſon at *Ealand* in *Yorkſhire*, about the year 1664 or before, had piled up in a barn many cart-loads of the pyrites, or braſs-lumps, as they were called by the colliers, for ſome ſecret purpoſes of his own: the roof of the barn happening to be bad, the pyrites were wetted by the rain; in this ſtate they began to ſmoke, and preſently *took fire*, and burned like red-hot coals *.

We have an account, in the Philoſophical

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* Power's Microſ. Obſer. p. 62.

loſophical Tranſactions for 1693 †; of a covetous maſter of a copperas work at *Whiteſtable* in *Kent*, who, in order to break his neighbour's work, had engroſſed all the pyrites or copperas-ſtone in the country: he built a ſhed over two or three hundred tons of theſe ſtones, to keep off the rain. In the ſpace, however, of ſix or ſeven months, the maſs (being probably wetted by the moiſture of the atmoſphere, or by the rain, which, notwithſtanding the ſhed, might have fallen upon it) *took fire* and burned for a week; it quite deſtroyed his ſhed, and diſappointed all his hopes of profit; for the pyrites was in part converted into a ſubſtance like melted metal, and in part it looked like red-hot ſtones: all the ſulphur was conſumed, and the neighbourhood was miſerably afflicted by the noxious exhalation which it ſent forth.

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† No. 213.

In the month of Auguſt 1751, the *Cliffs* near *Charmouth* in *Dorſetſhire took fire*, in conſequence of a heavy fall of rain after a hot and dry ſeaſon, and they continued at intervals to emit flame for ſeveral years.—Theſe Cliffs conſiſt of a dark-coloured bituminous loam, in which are imbedded large quantities of different kinds of the pyrites. The ſame kind of flame has been frequently obſerved in the *Corniſh* mines, and this mineral fire ſometimes leads to the diſcovery of a mine; but wherever it is found to exiſt, the iron pyrites is generally diſcovered near it*.

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* Philoſ. Tranſ. Vol. LII. p. 119.

There are ſome ſorts of earth from which alum is made, which abound ſo much with the pyrites, that the proprietors of the works are forced to keep them conſtantly well watered, in order to prevent their taking fire *.—But it would be uſeleſs to purſue this ſubject further; we have adduced proof ſufficient, that nature furniſhes materials, which, under certain circumſtances, may become the occaſion of ſubterraneous fires. The requiſite circumſtances are a proper quantity of the materials, a proper portion of water to moiſten them, and, perhaps, a communication with the air may be neceſſary. A ſmall quantity of the pyrites

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* Waller. Min. Vol. I. 25. — Henckel Pyritol. p. 312. — Minera. par M. Val. de Bomare, Vol. I. p. 296.

rites is ſufficient to kindle a fire; water is almoſt every where found in ſuch great plenty below the ſurface of the earth, that it conſtitutes one of the greateſt impediments to our ſinking pits to any great depth; and air, if it ſhould be thought abſolutely neceſſary to the ſpontaneous firing of the pyrites, may be conceived either to accompany the water in its dripping, or to deſcend into the innermoſt parts of the earth through the fiſſures which are found upon its ſurface. When a ſubterraneous fire is once kindled, it may be ſupported for ages by other ſubſtances, as well as by thoſe which firſt gave riſe to it: thus, if a quantity of the pyrites ſhould take fire in a ſtratum of coal, or of *ſhale*, or of any other ſubſtance ſtrongly impregnated with bitumen, the fire might continue till the ſtratum was conſumed *.

There are ſuch a great number of volcanos now ſubſiſting in every quarter of the globe, and ſo many unequivocal veſtiges of others, which in length of time have become extinct, that ſome philoſophers think they have reaſon on their ſide in ſuppoſing either, that the earth, at ſome conſiderable diſtance below its ſurface, is ſurrounded with a ſtratum of ignited matter of

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* There are ſome coaleries on fire now in Scotland, which were on fire in the time of Agricola.—Pennant's Tour in Scot. Part II. p. 201. See an account of the coaleries on fire in Staffordſhire, in Dr. Plott's Nat. Hiſt. of that County ; and of the ſubſtances ſublimed from the burning coal-pits at Newcaſtle in Philoſ. Tranſ. for 1676.

of a definite thickneſs ; or that the whole central part of it is nothing but a maſs of melted minerals, which every where ſtruggling for vent, burſts forth where there is the leaſt reſiſtance, ſhivering into rude fragments the ſuperincumbent cruſt of earth, and deluging with mountainous torrents of liquid fire the adjoining countries.

We do not know of what kind of materials the inward part of the earth is compoſed ; the water, coal, earths, ſtones, metals met with upon its ſurface, have, bulk for bulk, very different weights ; and a ſimilar inequality of ſimilar materials may take place at all depths below the ſurface. It has been gathered, however, from very ingenious obſervations and calculations, upon the attraction of the hill *Scheballein* in Scotland, that the mean denſity of the whole earth is about four times and a half the denſity of water, the mean denſity of ſtones, ſuppoſe Portland ſtone, being two times and a half the denſity of water*. Hence if this globe of earth could be weighed in a ſcale, it would require two equal globes and a half of Portland ſtone, or four equal globes and a half of water to balance it. The whole earth being ſo much heavier, bulk for bulk, than the general matter near its ſurface, it has been conjectured, that there muſt be ſomewhere within the earth, towards the more central parts, great quantities of metals, or ſuch like denſe matter, to counterbalance the lightneſs of the ſuperficial materials, ſo as to make up the whole weight of the earth. Suppoſing the diameter of the earth to be 7920 miles, and that it was compoſed of an inward globe 5110 miles in diameter, and of an outward ſpherical ſhell 1405 miles in thickneſs, the matter of the inward globe being as heavy nearly as melted ſilver, and the matter of the outward cruſt being as heavy, at a medium, as Portland ſtone; then would the weight of ſuch an inward globe, and ſuch an outward ſhell or cruſt, be together equal to the preſent weight of the whole earth. But conſidering the great compreſſibility of water, and of the ſtones and earth met with upon the ſurface of the globe, it is probable, that in deſcending towards its centre, the parts may be ſo condenſed as to make the weight of the earth what it is, without ſuppoſing its central parts to be compoſed of materials different from its ſuperficial parts*.

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* Philoſ. Tranſ. 1778. p. 784.

But to return to our experiment. I need uſe no arguments to prove that either the ſulphur, or the iron, or both, have undergone a great change during their fermentation: we can have no difficulty in thinking that the ſulphureous ſteams, heat, flame, and fire, which attended the mutual action of ſulphur and iron upon each other, could not have been produced without the bodies themſelves having ſuffered ſome change: this change is viſible from inſpecting the mixture before and after its fermentation; from a greyiſh colour it will be turned wholly black, or of a deep red; it will be rendered more manifeſt by taſting it: neither ſulphur nor iron have any taſte, nor has the mixture of the two any taſte before its fermentation; but after that is finiſhed, it has a very ſaline taſte. The nature of the ſalt contained in it will be examined in the next Eſſay.

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* See Mr. Michell's very ingenious Eſſay on Earthquakes.

ESSAY VI.

Of Vitriols, and the reputed Tranſmutation of Iron into Copper.

THE nature of the reſidue reſulting from the fermentation of iron filings and ſulphur, may be eaſily aſcertained. Its taſte indicates that it contains ſome ſaline ſubſtance; in order to ſee what that ſubſtance is, it muſt be boiled in water; by this means all the ſalt contained in it, of whatever quality it may be, will be extracted. The water containing the ſalt in ſolution being filtrated, evaporated, and cryſtallized, according to the uſual mode, we ſhall obtain large ſaline cryſtals, of the colour of an emerald, and of the figure of a lozenge. This ſalt is called *green vitriol*; green from its colour, and vitriol from its reſembling *vitrum*, or glaſs, by its tranſparency.

This ſalt certainly did not exiſt, either in the ſulphur, or in the iron, it muſt therefore ariſe from their mixture; but from a mere mixture of ſulphur and iron, no ſalt can be extracted, unleſs the ſubſtances of which it conſiſts have been, by ſome means or other, decompoſed. The reader may probably recollect, that ſulphur is compoſed of two things,—of an *acid*, and of *phlogiſton*.—Iron alſo is compoſed of two things,—of an *earth*, and of *phlogiſton*. During the fermentation of the maſs of ſulphur and iron, the phlogiſton, or inflammable part of them both, is diſperſed; and, indeed, in being diſperſed, it becomes the cauſe of the heat, fire, and flame, obſervable in that maſs. The inflammable part, both of the ſulphur and of iron, being diſperſed, there remains the *acid* of the ſulphur, and the *earth* of the iron. The acid of ſulphur is a very ſtrong acid, it diſſolves many bodies with great facility, and when it is diluted with water, it, in particular, diſſolves iron; and, by its union with the earth of iron, it compoſes the ſalt in queſtion.

That this is a true explanation of the origin of this ſalt, will appear evident from the following conſideration. If into a quantity of the acid procured from the burning of ſulphur, you put a piece of iron, the iron will be wholly diſſolved in the acid, as ſalt is diſſolved in water; and if you ſaturate the acid with iron, and then evaporate and cryſtallize the ſolution, you will obtain a green vitriol, ſimilar, in every reſpect, to that obtained from the reſidue of which we are ſpeaking.

The compoſition of green vitriol has been fully explained, and its decompoſition or analyſis will ſtill further illuſtrate its nature, and leave no doubt of the truth of the propoſition which aſſerts, that—*green vitriol* conſiſts of the *acid of ſulphur* united to *iron*, or more properly to the *earth of iron*.

If you put 16 ounces of freſh

green vitriol into a retort, and diſtil them till nothing more can be forced into the receiver, by the utmoſt violence of a long continued fire, you will find in the receiver about 11 ounces of an acid liquor, ſmelling, in all the trials that I have ever made, very ſtrongly of ſulphur; and in the retort you will find about 5 ounces of an earth, of a deep red or purpliſh colour. The acid liquor, by combining it again with iron, may be made into vitriol; and the earth, by being properly melted in conjunction with any matter which will reſtore to it its inflammable principle, may be made into iron. The proportionable quantities of acid and earth procurable from green vitriol by diſtillation, are purpoſely expreſſed in terms rather indefinite, becauſe that proportion is ſomewhat variable in different vitriols.

The earth remaining from the diſtillation of vitriol is called *Colcothar.* I would not have troubled the reader with ſo barbarous a name, but for an obſervation relative to its uſe, which may be worth mentioning.

Colcothar is ſold for ten pence a pound in *Paris*; it is uſed for giving the laſt poliſh to plate-glaſs, at the great manufactury in the ſtreet *St. Antoine.* The largeſt plate of glaſs which had ever been poliſhed in that manufactury, they informed me ten or twelve years ago, was ten feet in length, and ſix in breadth. The glaſs is brought from *Picardy*; it is there melted in large crucibles, and ſpread, whilſt liquid, upon a table covered with a ſheet of copper; much after the ſame manner in which plumbers caſt a ſheet of lead. The plate of glaſs, when firſt caſt, is an inch in thickneſs; its aſperities are ground away with a coarſe kind of grit-ſtone, with ſand, and emery, of different degrees of fineneſs, and it is at laſt poliſhed by colcothar.

I do not know whether the uſe of colcothar is adopted in our Engliſh plate-glaſs manufactury near *Preſcot* in *Lancaſhire*, having not been fortunate enough to obtain permiſſion to ſee it. But, both to the proprietors of that manufactury, and to the patentees for poliſhing marble at *Aſhford* in *Derbyſhire*, I take the liberty to ſuggeſt, that colcothar, which is very cheap, might perhaps render the uſe of *putty*, or calcined tin, leſs neceſſary.—Would it not be poſſible to apply the ſame kind of machines by which marble is poliſhed to the poliſhing of plate-glaſs? — But to return from this digreſſion.

The acid ſeparated from vitriol, by diſtillation, is called the *vitriolic acid*. From what has been ſaid, relative to the formation of vitriol, it manifeſtly appears to be the ſame with that which enters into the compoſition of ſulphur; and indeed the main part of what is ſold as vitriolic acid, is now obtained by collecting the vapour of burning ſulphur, and not, as it uſed formerly to be, from the diſtillation of vitriol.

It muſt not be imagined, that the acid liquor procured from the diſtillation of the 16 ounces of vitriol, conſiſts intirely of the vitriolic acid; it conſiſts of that acid diluted with a large portion of pure water. If care had been taken to ſeparate the different products as they aroſe, during the diſtillation, we might have procured, by a very gentle fire, ſix or ſeven ounces of water wholly inſipid: this is the water of cryſtallization before ſpoken of*; it is called the *phlegm of vitriol.* After the ſeparation of this water, by a ſtronger degree of heat we ſhould have obtained an ounce or two of water ſlightly impregnated with an acid: this is called, *ſpirit of vitriol.* Laſtly, with a very violent fire we ſhould have gotten a very ponderous and ſtrong acid, having an unctuous appearance, and from that appear-

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* P. 125.

ance generally, but improperly, called, *oil of vitriol.* This oil of vitriol is not always fluid; ſometimes, when it is exceedingly ſtrong, it has been obſerved to become ſolid: in that ſtate it is denominated, *glacial,* or *icy oil of vitriol.*

It was ſhewn in the laſt Eſſay, that natural combinations of iron and ſulphur were ſubject to the ſame ſpontaneous changes obſervable in the artificial mixtures of theſe ſubſtances; and hence we may clearly apprehend the manner in which what are called *native vitriols* are formed in mines and other ſubterraneous cavities. The pyrites exiſting in theſe places being naturally decompoſed by the ſulphur's parting with its phlogiſton, the water which is always dripping in mines, diſſolves the vitriol generated in the decompoſed pyrites; and being afterwards evaporated, either by the heat, or the current of air ſubſiſting in the mine, the vitriol is found in its cryſtalline form, either projecting like icicles from the top and ſides of the mine, or lying in cavities at its bottom. The cryſtals of *native vitriol* are more or leſs regular, according to the circumſtances attending the evaporation of the water, and they are of different colours according to the quality of the pyrites; for together with the ſulphur and iron, the chief conſtituent parts of the pyrites, there is ſometimes combined copper, and other metallic matters, which being diſſolved by the acid of the ſulphur at the ſame time that the iron is diſſolved, a mixed vitriol is produced, the colour of which is ſometimes whitiſh, more generally it conſiſts of different ſhades of green and blue.

Native vitriol is often met with in our coal mines. From an old *Cannel-coal* pit near *Wigan* in Lancaſhire, I procured a conſiderable quantity of it very well cryſtallized; and Dr. Rutty has obſerved, that the vitriolic water at *Haigh* in Lancaſhire is the ſtrongeſt in Britain, yielding 1920 grains of vitriol from a gallon of water *.

When I was at *Whitehaven*, ſome years ago, I was informed by the very intelligent ſuperintendent of the coal works in that place, that the bottom of a pump of caſt iron, which had ſtood a long time in a well of *vitriolic water*, was ſo much ſoftened, that, after removing a thin coat of ruſt, he was able to cut it with a knife, as eaſily as he could cut black lead; it had preſerved its grain, and was not in any wiſe altered, except in being ſoftened.

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* Philoſ Tranſ. 1756. p. 650. See alſo, for an Examination of this *Haigh* water, which ſprings from a ſtratum of the cannel-coal, Leigh's Tentamen Philo. de Fonte Med. in Agro Lancaſ. C. I.

At that time, I attributed this ſoftening of the iron to the action of the *vitriolic water*, and thought it a very ſingular phenomenon: in this, however, I was miſtaken; ſea water has the ſame effect. Some iron cannon, which had lain in the ſea upwards of ſixty years, were weighed up, and the iron was found to be as ſoft as tin; though in 24 hours, by being expoſed to the air, it recovered its original hardneſs *. This ſoftening of iron is not an effect peculiar to the action of either vitriolic or ſea water: I have ſomewhere read of an experiment of ſoftening iron by ſmearing its ſurface with the acid of vitriol; and I have heard of a gentleman, who having frequently ſtirred ſaline draughts with his penknife, found its temperature much ſoftened thereby. *Diodorus Siculus* mentions a cuſtom of the *Celtiberians*, by which they made their arms of incomparable hardneſs; they buried plates of iron under the earth, till the weaker part of the iron was conſumed by the ruſt, and they fabricated their arms from the remainder ‡. The inhabitants of *Japan* are ſaid to make uſe of the ſame artifice †.—The time, however, in which the iron is ſuffered to lie in the ground, muſt not be too long; for the iron, inſtead of being ſoftened and meliorated, will in length of time be wholly changed, as is ſaid to have happened to ſome Spaniſh cannon made of hammered iron, which had lain many years under the old fort at *Hull* in *Yorkſhire*; the iron being changed into a brittle kind of ſtone reſembling an iron ore, and refuſing to obey the action of the magnet *.

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* Hiſt. de l' Acad. des Scien. a Paris, an. 1756.

‡ Diod. Sic. L. V. p. 356.

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† In itinerariis referunt aliqui de Japanenſibus quod ferrum ſuum in contos excuſum locis paluſtribus immergant, et ibi tamdiu relinquant, dum ad multam partem ferrugine ſit conſumtum; exemtum dein e novo excudant, et iterum in paludi per ſpatium 8 vel 10 annorum recondant, uſque dum iterum in aqua paludinoſa ſalſa admodum exeſum ſit: pars ferri quæ reſtat ſpeciem chalybis referre perhibetur, exinde dein vomeres fabricant, exque ferro ſic rubiginoſo inſtrumenta ſua et utenſilia conficiunt. Sweden. de Ferro, Vol. I. p. 194.

Modern chemiſts apply the name *vitriol*, to every combination of the acid of ſulphur with any metallic ſubſtance; three, however, of theſe combinations are more particularly diſtinguiſhed, being of great uſe in various manufactures, —*green vitriol* — *blue vitriol* — *white vitriol*. The acid in all theſe vitriols is the ſame: the metallic baſis of the green vitriol we have already ſeen is iron, that of the blue vitriol is copper, and that of the white vitriol is zinc. Vitriol is very commonly called by the manufacturers *copperas*: thus we conſtantly hear of green, blue, and white copperas. The conſtituent parts of the different kinds of vitriols were not underſtood by the ancients ſo well as they are at preſent; they ſeem to have had an idea, that copper was the baſis of them all: hence the Greek term for vitriol, *chalcanthos*, the effloreſcence of copper; and the Latin one, *cuperoſa*, or *cupri roſa*, the flower or effloreſcence of copper; from which the French *couperoſe*, and our *copperas*, are evidently derived.

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* Liſter's Journey to Paris, p. 84. Ed. 1699.

The vitriols which nature prepares, are never to be met with in commerce; they ſerve to adorn the cabinets of the curious, but they are neither ſufficiently pure for the purpoſes to which common vitriols are applied, nor are they found in ſufficient quantities to anſwer the demand which is made for them. Green vitriol is made at *Deptford*, and other places, from a ſpecies of the pyrites found on *Shepey* Iſle, the Iſle of *Wight*, and various parts of the *Eſſex*, *Kentiſh*, *Suſſex*, and *Dorſetſhire* coaſts. Large quantities of the pyrites are laid in heaps in the open air, on beds properly prepared; in half a year, a year, two years, ſooner or later, according to its quality, the pyrites acquires a ſpontaneous heat; that heat, without being increaſed to ſuch a degree as to fire the pyrites, inſenſibly diſperſes the inflammable principle of the ſulphur, one of the conſtituent parts of the pyrites; the acid of the ſulphur being thus diſengaged from the inflammable principle, unites itſelf to the other principal conſtituent part of the pyrites, the iron, and forms green vitriol. The vitriol thus formed is waſhed from the pyrites' bed by the rain: the rain-water which has diſſolved the vitriol of the pyrites, cannot ſink into the earth, the bed on which the pyrites is ſpread being formed of clay; and being made, moreover, in a ſloping poſition, the diſſolved vitriol runs into receptacles properly placed to receive it, and being boiled with old iron till it is of a proper conſiſtency, it is run off into coolers, and left to cryſtallize. Vitriol may be made without the uſe of old iron, but the liquor which drains from the pyrites being often not ſaturated with iron, the iron is added to ſaturate the acid, and at the ſame time to purify it from any particles of copper it may chance to contain; by this means a pure iron vitriol is obtained, which is known in commerce under the name of Engliſh vitriol. The quantity of old iron, in ſome works, amounts to two hundred weight in making a ton of vitriol.

Much after the ſame manner, vitriol is made from the pyrites found amongſt coal; there are manufacturies of it near *Wigan*, at *Whitehaven*, at *Newcaſtle upon Tyne*, and in ſeveral other parts of the kingdom. But all the vitriol works have ſunk in value of late years; the home conſumption of vitriol being much diminiſhed ſince the acid, which uſed to be procured from the diſtillation of vitriol, has been obtained from the burning of ſulphur.

It is not eaſy to determine when this method of making vitriol was introduced into England. In the very beginning of Queen Elizabeth's reign, a patent was granted to Cornelius Devoz, for making alum and copperas*; but it was not till towards the end of the laſt century, that this art of making vitriol was brought to ſo great perfection as to enable us to export any of it †; and, indeed ‡, a very deep and judicious inquirer into things of this kind aſſures us, that "at the latter end of the laſt century, we imported annually about 500 tons of vitriol, and that we now export upwards of 2000 tons." It appears, that there was exported, from the

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[*] Oper. Min. explicat. p. 26.

[†] Boyle's Works.

[‡] Campb. Survey of Brit. Vol. II. p. 21.

port of London alone, near 400 tons of copperas in three months, January, February, and March, 1776 *. A ſmall quantity of vitriol, perhaps to the annual amount of 50 or 60 tons, is ſtill imported into England; ſome particular dyers and other artiſts being of opinion, that the foreign vitriol, as containing a little copper, is more uſeful to them than the Engliſh vitriol.

It may eaſily be known whether green vitriol contains any copper; we need only rub the vitriol to be examined upon a moiſtened piece of poliſhed iron, for if there is any copper in its compoſition, the iron will be changed into a copper colour. This experiment renders it neceſſary to

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* See Sir Charles Whitworth's Reg. of Trade, No. I.

to explain to the reader two terms frequently met with in chemical books—*affinity* and *precipitation.*

When two heterogeneous bodies, as an acid and iron, coaleſce together, and conſtitute by their union a third body different from either of them, their union is ſaid to proceed from their mutual *attraction*, or, in the language of German philoſophy, from their mutual *affinity.* It may reaſonably be conjectured, that the affinity of the ſame body, of the ſame acid for inſtance, may be different with different bodies; its action upon iron may be different from its action upon copper; and its action upon any metallic ſubſtance may be different from its action upon any alkaline or earthy ſubſtance; becauſe, from whatever attractive powers we ſuppoſe its action upon any body to proceed, it ſeems probable enough, that their effects will be modified, according to the nature of the ſubject upon which they are exerted. A few inſtances will make this matter clear.

Spirits of wine very readily diſſolve a portion of camphor; that is, the particles of the ſpirits of wine ſo powerfully *attract* the particles of camphor, that they unite themſelves with the camphor in ſuch a way, as to compoſe with it a pellucid fluid. Spirits of wine, however, more powerfully attract water than they attract camphor; for if you mix water with camphorated ſpirits of wine, you will ſee that the ſpirits quitting their connexion with the camphor, will unite themſelves with the water, and the camphor being lighter than water, will riſe up to the ſurface. Lavender water conſiſts of the oil of lavender diſſolved in ſpirits of wine. Into a glaſs of water, drop a few drops of lavender water; the ſpirits of wine will quit the oil, in order to unite themſelves with the water, and the oil being lighter than water will float upon its ſurface. In both theſe caſes, the ſpirits of wine are ſaid to have a greater affinity with water, than with camphor or oil of lavender.

Into a ſolution of green vitriol, drop a ſolution of pot-aſh, ſalt of tartar, or any alkaline ſalt; the vitriolic ſolution will let fall a ſediment: continue to mix the alkali with the ſolution of vitriol, till no more matter falls to the bottom; the matter which falls to the bottom, is ſaid to be *precipitated*, and it is often called a *precipitate*. This effect may be thus explained:—green vitriol conſiſts of two things,—of an acid, and of an iron earth; but the acid has a greater diſpoſition to unite itſelf with any alkali, than it has to continue united with the earth of iron; when therefore an alkali is preſented to it, it quits the iron earth, which, thus wanting its ſupport, falls to the bottom, and unites itſelf with the alkali. The acid of vitriol is therefore, on this account, ſaid to have a greater affinity with any alkaline ſalt, than with iron, becauſe any alkaline ſalt will ſeparate the iron from the acid. What is precipitated may be made into iron; and if the liquid which floats upon the precipitated earth, be evaporated and cryſtallized, it will give the very kind of ſalt which would ariſe from a direct combination of the acid of vitriol with the alkali which occaſioned the precipitation. I will mention one other inſtance.

Blue vitriol conſiſts of copper united with the acid of vitriol: if to a ſolution of blue vitriol you add a piece of bright iron, it will preſently become covered with a coppery coat, the copper will all be *precipitated*, and the iron will be *diſſolved* in its ſtead. The proof of this reaſoning is eaſy: the matter which is precipitated may be melted into copper, and the liquid part may, by evaporation and cryſtallization, be made, not into *blue*, but into *green vitriol*; that is, into a combination of the vitriolic acid and iron. Hence it is ſaid, that the acid of vitriol has a greater affinity with iron, than it has with copper, becauſe it quits copper to unite itſelf with iron. In order to be convinced of the truth of what is advanced, we need only dip a bright key into a ſolution of blue vitriol, and we ſhall ſee the key preſently becoming covered with a copper-coloured pellicle.

This experiment explains to us, in a very ſatisfactory manner, the nature of that *tranſmutation of iron into copper*, which travellers have been ſo much ſurpriſed at. Agricola ſpeaks of waters in the neighbourhood of *Newſol* in *Hungary* which had the property of tranſmuting the iron which was put into them into copper [*]. In the year 1673, our countryman Dr. Brown viſited a famous copper mine at *Herrn-Grundt*, about ſeven Engliſh miles from *Newſol*; he informs us that he there ſaw two ſprings, called the old and new *ziment*, which turned iron into copper. The workmen ſhewed him a curious cup made of this tranſmuted iron; it was gilt with gold, had a rich piece of ſilver ore faſtened in the middle, and the following inſcription engraved on the out-ſide:

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[*] Agric. Foſ. L. IX. p. 347.

Eiſen ware ich, kupſer bin ich,
Silver trag ich, gold bedeckt mich.

7

Copper I am, but *iron* was of old,
Silver I carry, covered am with gold*.

It was even at that time, he ſays, contended by ſome, that there was no real tranſmutation of iron into copper, but that the ziment water, containing vitriol of copper, and meeting with the iron, depoſited its copper; and it ſeems as if he would have acceded to this opinion, could he have told what became of the iron. It is now very well underſtood what becomes of the iron; it is taken up by the water, and remains ſuſpended in it, in the place of the copper; ſo that this tranſmutation is nothing but a change of place; and as the copper is precipitated by the iron, ſo the iron might be precipitated by pot-aſh, or any other ſubſtance which has a greater affinity with the acid of vitriol than iron has.

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* Brown's Travels, Ed. 1687. p. 69.

The cauſe of the impregnation of theſe copper waters in Germany is not difficult to be explained. Moſt copper ores contain ſulphur, and when the ſulphur is in any degree decompoſed, its acid unites itſelf to the copper, and forms blue vitriol, which is the ſubſtance with which the waters iſſuing from the copper-mines are impregnated. It has been the cuſtom in Germany, for ſome centuries, to collect the copper contained in theſe waters; the method is ſimple: into pits filled with the coppery water they put old iron; the iron is diſſolved, and the copper is precipitated, and being raked out in the form of mud, it is afterwards melted into very fine copper. The quantity of copper procured by an hundred tons of iron, is not always the ſame; it ſometimes amounts to 90 tons, and ſeldom to leſs than 84[*].

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[*] Miſcel. Curi. Germ. Ann. 6 & 7, p. 158, where

The progreſs of arts is in many inſtances wonderfully ſlow. Though this method of obtaining copper has been long practiſed in Germany, yet it is but of late years that any ſucceſsful attempts of this kind have been made in either England † or Ireland; and that they have been made at all has, in Ireland at leaſt, been owing not to the example which had been ſet in Germany, but to an accident.

There are very celebrated copper-mines at *Arklow* in the county of *Wicklow* in Ireland; and from theſe mines

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where there is mention made of an oak leaf being changed into copper—the iron contained in the leaf, probably precipitating the copper.

† An attempt was made in 1571, to tranſmute iron into copper, near Pool in Dorſetſhire. Hutch. Hiſt. of Dorſ. Vol. II. p. 110.

mines there iſſues a great quantity of water, ſtrongly impregnated with the vitriol of copper. One of the workmen having accidentally left an iron ſhovel in this water, he found it, ſome weeks after, ſo incruſted with a coat of copper, that it was thought to be changed into copper. The proprietors of the mines, in purſuance of this hint, made proper pits and receptacles for the water, and have obtained, by means of ſoft iron bars put into the coppery water, ſuch quantities of copper, as render the ſtreams of as much conſequence as the mines. One ton of iron produces near two tons of copper mud; and each ton of mud produces, when melted, 16 hundred weight of copper, which ſells for 10 pounds a ton, The progreſs of arts is in many inſtances wonderfully ſlow. Though this method of obtaining copper has been long practiſed in Germany, yet it is but of late years that any ſucceſsful attempts of this kind have been made in either England † or Ireland; and that they have been made at all has, in Ireland at leaſt, been owing not to the example which had been ſet in Germany, but to an accident.

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There is a mountain in the iſle of *Angleſey*, called *Paris* mountain, which abounds in copper ore; the bed of ore being above forty feet in thickneſs. The leſſees of this mine annually raiſe between ſix and ſeven thouſand tons of merchantable ore, and daily employ above forty furnaces in ſmelting it. The ore is not rich in copper, but it contains a great quantity of ſulphur, which muſt be ſeparated from it, before it can be fluxed into copper. The ore is accordingly roaſted; the phlogiſton, together with part of the acid of the ſulphur, is, by the violence of the fire to which it is expoſed in roaſting, diſperſed into the air: another part of the acid attacks and diſſolves the copper. The water in which the roaſted ore is waſhed is ſo ſtrongly impregnated with copper, that they have found it uſeful to adopt the German method of precipitating it by means of old iron, and they have obtained in one year near one hundred tons of copper precipitated from this water.

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* Philoſ. Tranſ. for 1751 and 1752, p. 502. and for 1756.—Iron often contains gold; the vitriolic acid has no action upon gold; is not the gold contained in the iron mixed with the precipitated copper, and may it not be worth while on this account to aſſay this copper?

The water, after the copper has been precipitated by means of iron, is at preſent thrown away; it would, by evaporation, yield *green vitriol*; and as above one hundred tons of iron muſt be employed in obtaining the forementioned quantity of copper, it may deſerve to be conſidered, whether a *manufactury of green vitriol* might not be eſtabliſhed at this and at all other places where *copper* is obtained by *precipitation*. One hundred tons of iron would yield, at the leaſt, two hundred tons of vitriol; which, at the low price of three pounds per ton, would be more than ſufficient, I ſuppoſe, to pay the expence of extracting it; eſpecially, as means might be contrived of evaporating the watery ſolution, by a proper application of part of that heat, which is at preſent loſt in all the great ſmelting-houſes. There are other purpoſes to which this water might be uſefully applied, which I cannot inſiſt upon in this place.

The principal uſe of green vitriol is, in dying, and in making of ink. When the vitriol is diſſolved in water, the iron contained in it becomes black by the addition of an infuſion of gall-nuts. Galls are excreſcences from the oak; they are formed from the exudation of the juices of the oak: this exudation is not ſpontaneous; it proceeds from the puncture made in the bark by an inſect: in the hole which it has made, it depoſits its egg, and the exuding juice hardening, forms a proper *nidus* for it. Moſt of the galls have holes in them, the young inſect having eaten its way through the ſubſtance in which it was hatched: in many of thoſe which have no holes, the inſect may be diſcovered in the inſide, by breaking the gall. The property which an infuſion of galls has, of tinging a ſolution of vitriol black or purpliſh, renders it ſerviceable in diſcovering the minuteſt portion of iron in chalybeate waters. I took one grain of vitriol (a grain of vitriol does not contain quite half a grain of iron) and diſſolved it in 15 gallons of water; the water, upon the addition of an infuſion of galls, became ſenſibly purple. Other *aſtringent* vegetables have a ſimilar effect on vitriol, but not in the ſame degree.

I will conclude this ſubject with mentioning an experiment, which, when proſecuted by a ſkilful manufacturer, may, I ſhould hope, ſome time or other, become of general ſervice.

I took a piece of dry oak, which had been felled about a year; I raſped off from the bark, from the ſap, and from the heart of the wood, equal weights, and put them into equal portions of hot water. After they had ſtood ſome time, it was apparent, that the bark had given an higher colour to the water than the heart had done; and that the water in which the ſap was put, had extracted the leaſt colour. Into equal portions of a ſolution of green vitriol, I put equal parts of theſe ſeveral infuſions, expecting to have ſeen the vitriol turned black by them all; but the event was, that the *ſap* infuſion produced very little change of colour; the *bark* infuſion gave a dark brown; and the *heart* infuſion inſtantly gave one of the moſt *vivid blues* I ever ſaw. If the raſpings of heart of oak be boiled for an hour in water, they loſe this property of forming blue with vitriol; but the cold infuſion forms a fine blue; and if a ſolution of vitriol be poured upon the raſpings, the whole is changed into a blue maſs.

ESSAY VII.

Of Nitre or Saltpetre, and the application of its Acid to the inflammation of Oils, and the congelation of Quickſilver.

SOME of the more ancient chemical writers were accuſtomed to make a diſtinction between *nitre* and *ſaltpetre*; they are now uſed as ſynonymous terms. The conſtituent parts of nitre are two; — an *acid*, and the *vegetable fixed alkali*. This propoſition may be proved both by the *decompoſition* and the *compoſition* of nitre.

Nitre may be *decompoſed* in the following manner. — Upon two parts of nitre by weight, pour one part by weight of ſtrong acid of vitriol, and diſtil the mixture. You will obtain thereby, a very ſtrong *acid*, of a yellowiſh colour, and a moſt ſuffocating ſmell, and which has the ſingular property of emitting *red fumes*; by the addition of water the colour may be rendered *blue* or *green*, but the fumes will ſtill be red. This is the *acid* or *ſpirit of nitre* *; and it is ſometimes called *Glauber's fuming ſpirit of nitre*, becauſe Glauber is generally ſuppoſed to have been the firſt inventor of this manner of extracting it.—Two things were diſtilled together, the acid of vitriol and nitre. Nitre itſelf, we ſay, conſiſts of two things; of a peculiar kind of acid, and of the vegetable fixed alkali: the acid, we have ſeen, may be extracted by diſtillation; there ought, therefore, to remain, in the veſſel uſed for the diſtillation, the *acid of vitriol* and the *alkali* of the *nitre:* and there really does remain nothing elſe; for the reſidue, when diſſolved and cryſtallized, is found to be the very ſame kind of ſalt, in all its properties, as would ariſe from the direct combination of the acid of vitriol with the vegetable fixed alkali. We need not wonder, that we do not find the alkali of the nitre and the acid of vitriol in their ſeparate forms, but united together into a particular kind of ſalt; for the acid of vitriol has a ſtrong diſpoſition to diſſolve all kinds of alkalies; it attracts them with more force than they are attracted by any other acid; and it was in conſequence of this ſuperior attraction of the acid of vitriol, that the acid of nitre was diſengaged from its other component part: the acid of vitriol expelled, as it were, the acid of nitre from the fixed alkali, and ſubſtituted itſelf in its place.

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* The word ſpirit is uſed by chemical writers with great latitude; it is applied to *acids*, as the ſpirit of vitriol, of nitre, of ſea ſalt, &c. and to *volatile alkalies*, as the ſpirit of ſal ammoniac, of hartſhorn, &c. and the inflammable fluid obtained by diſtillation from wine, &c. is eminently entitled to the name of ſpirits.

There are various other methods of decompoſing nitre beſides that which has been mentioned: thoſe who prepare *aqua fortis*, uſually diſtil the nitre in conjunction either with clay or with green vitriol, calcined to a certain degree. The acid of vitriol is contained in many kinds of clay, as well as in green vitriol; but it leaves both the clay, and the iron of the green vitriol to unite itſelf with the alkali of the nitre; and the acid of nitre being thus ſet at liberty by the intervention of the acid of vitriol, and being alſo of a volatile nature, it is eaſily made to aſcend in vapour, which, being collected in proper veſſels, becomes the *aqua fortis* of the ſhops.

It may appear from what has been ſaid, that the *acid of nitre* and *aqua fortis* are but different names for the ſame thing: the matter is not quite ſo, unleſs the reader will underſtand by aqua fortis, *pure* aqua fortis; for whenever the acid of vitriol, or any ſubſtance containing it, is uſed in the proceſs for decompoſing nitre by diſtillation, a portion of the acid of vitriol is diſtilled in conjunction with the acid of nitre: hence the common aqua fortis may be conſidered as a pure acid of nitre, mixed with a portion of the acid of vitriol. This portion of the acid of vitriol is thought to render the aqua fortis fitter for the purpoſes of ſome particular artiſts: thus *engravers* and *etchers* uſe an aqua fortis which contains about one tenth of its weight of the acid of vitriol; and the proportion of acid of vitriol, which enters into the aqua fortis uſed by *dyers*, is ſtill much greater. It is neceſſary for *refining ſilver*, and for many other purpoſes, to have the acid of nitre quite pure. This may be effected, either by purifying the common aqua fortis by various means well known to chemiſts, or by diſtilling nitre with ſome ſubſtance which contains no acid of vitriol; for though it be certain, that the acid of vitriol is very ſerviceable in diſengaging the nitrous acid from its baſis, yet it is alſo certain, that the nitrous acid may be diſengaged, without the aſſiſtance of the vitriolic acid: thus I remember having many years ago obtained a very ſtrong *fuming* acid of nitre, by diſtilling *nitre* with *white ſand*, which contains no acid of vitriol.

The artificial *compoſition* of nitre is eaſily effected. Take a portion of the nitrous acid, and pour it into a ſolution of pot-aſh, of ſalt of tartar, or of any other vegetable fixed alkali, till no more efferveſcence is obſerved:

ſerved: evaporate and cryſtallize the compound, and you will obtain a perfect nitre. This is uſually called a *regenerated nitre*; and we may often ſee cryſtals of nitre almoſt inſtantaneouſly produced, by mixing a ſolution of pot-aſh with a nitrous acid of a due degree of ſtrength.

In time of war with an enemy who has plenty of pot-aſh but no ſaltpetre, the ſupplying him with *aqua fortis* ought to be prohibited under as ſevere penalties as the ſupplying him with ſaltpetre itſelf; becauſe, if he can procure the aqua fortis, it will be an eaſy matter for him, by mixing it with his pot-aſh, to make regenerated nitre. The nitre may come a little dearer to him than common nitre would do; but it is at the ſame time purer, and fitter for the preparation of gunpowder.

Though chemiſtry exhibits to us a great variety of ſtriking phenomena, yet there is none more ſurpriſing than that which attends the mixing of the *fuming acid of nitre* with *oil of turpentine.* If you mix theſe two fluids together in the ſevereſt weather, and when they are ſeverally colder than ice, you will ſee them inſtantaneouſly catching fire, and burſting forth into a dreadful flame. This experiment does not always ſucceed with the acid of nitre which may ordinarily be procured from the ſhops, becauſe it is ſeldom ſufficiently ſtrong; but when it does ſucceed, there is great danger in making it, eſpecially if the quantities which are mixed together amount even to a few ounces. I have ſeveral times ſeen a thick column of flame and ſmoke, above twenty feet in height, inſtantaneouſly produced, by pouring, at once, a pint of the fuming acid of nitre on a pint of oil of turpentine. Whoever undertakes to make a ſimilar inflammation, would do well to uſe the precaution of faſtening the veſſel containing the acid to the end of a long pole, to prevent his being burned by the drops of inflamed oil, which are diſperſed, laterally, by the exploſion to a great diſtance.

Borrichius, in the year 1671, is thought to have been the firſt perſon who noticed the phenomenon here ſpoken of: ſince that time the chemiſts of all countries have employed much attention in repeating and diverſifying this celebrated experiment. In the Philoſophical Tranſactions for 1699, we have a table expreſſing, at one view, the effect which the acid of nitre has upon a variety of other oils, as well as upon the oil of turpentine: we there find enumerated 12 ſorts of oils, which, when mixed with acid of nitre, efferveſced, and exploded with a flame; 18 ſorts which efferveſced, but did not take fire; and 9 ſorts which neither efferveſced nor took fire. In addition to the information contained in this table, we are indebted to the French chemiſts, for a variety of intereſting memoirs on the inflammation of oils; both by the ſimple nitrous acid, and by that acid when mixed with the acid of vitriol. The reader will, perhaps, be ſatisfied with a general reference to the moſt approved authors * on the ſubject; eſpecially as there is not any very ſatisfactory ſolution given of the phenomenon.

We know that a piece of iron may be hammered till it glows with heat; that the axle-tree of a carriage may be ſo heated, by the rapidity of the motion, or the violence of the friction, as to inflame the wood contiguous to it; that two pieces of wood may

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* See Mem. del l' Acad. de Par. Ann. 1701. 1726. 1747. and Macquer's Elem. of Chem. Vol. II. p. 149. Eng. Tranſ. and eſpecially Muſſchenbroek's Additions to the experiments of the Florentine Academy. This induſtrious philoſopher has there given us above 200 different experiments, illuſtrating the change of temperature ariſing from the mixture of water; of ſpirits of wine; of vinegar; of the mineral acids; with a great variety of other bodies.

may by friction be made to take fire; and we infer from theſe, and other appearances of the ſame kind, that the motion excited by the action of particular acids upon particular oils, is ſufficient to produce that degree of heat which is requiſite to inflame the oils.

It does not ſeem to be a ſimple mixture of two ingredients which produces heat; they muſt act upon each other in a manner different from what accompanies a ſimple mixture, and this action does not always take place immediately. Thus, if we mix 2 parts of ſpirit of wine with 1 part of freſh fuming acid of nitre, the mixture will often remain cold for near ten minutes, but it will at laſt begin to acquire a great degree of heat, and it will boil with great violence for a conſiderable length of time. In like manner, by mixing together equal bulks of ſtrong acid of vitriol and water, we may excite a degree of heat greater than that in which water boils: but it is not a ſimple mixture which takes place on this occaſion, the very texture of the bodies ſeems to be broken; for the compound occupies leſs ſpace than what the two ingredients would have occupied, had there only been a ſimple mixture. A pint of water mixed with a pint of oil of vitriol will not make a quart, as it would do, if mixed with a pint of milk; but then no heat would attend its mixture with milk, and a very great degree of heat attends its mixture with the acid of vitriol. It cannot be ſaid, that the acid of vitriol is received into the pores of the water; for then a ſmall portion of acid might be diſſolved in a large portion of water, without augmenting its bulk*; but the very form of the bodies is changed; there is, in the words of Dr. Hooke, (who firſt obſerved that acid of vitriol and water when mixed together poſſeſſed leſs ſpace than when ſeparate) a *penetration of dimenſions*‡.—Is heat ever excited by the mixture of two fluids, when the bulk of the compound is equal to the ſum of the bulks of the two ingredients?

Strong acid of nitre, when mixed with common water, or with ſnow water, produces a great degree of heat; when mixed with water congealed

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[*] Philoſ. Tranſ. 1770. p. 353.

[‡] Haukſbee's Exp. Ed. 1719. p. 294.

gealed into ice, or ſnow, it produces the greateſt degree of cold which has ever been obſerved on the ſurface of the earth; and this property of the acid of nitre has given occaſion to one of the fineſt diſcoveries of the preſent century,—the converſion of quickſilver into a malleable metal.

In the year 1759, upon the 14th day of December old ſtile, there was obſerved a greater degree of *natural cold* at *Peterſburgh*, than had ever before been noticed, ſince the time that the Academy had kept Meteorological regiſters; Fahrenheit's thermometer ſtanding at 66 degrees below the freezing point. In a few days the cold grew more intenſe, ſo as to make the thermometer, on the 26th of the ſame month, ſink to 74$\frac{2}{5}$ degrees below freezing. This is eſteemed the greateſt degree of natural cold which has hitherto been obſerved at Peterſburgh. This cold, though very great when compared with what we experience in England in the ſevereſt ſeaſons, is far leſs than what is ordinarily felt in *Siberia*; 120 degrees below the freezing point, having been often obſerved; and on the 5th of January 1735, the thermometer fell to 157 degrees below freezing*. When this degree of cold was firſt publiſhed to the world by Gmelinus, who made the obſervation at *Jeneſeiſk*, many ſuſpected the truth of the account, or queſtioned the accuracy of the obſervation; but their ſuſpicions were ill founded, for an equal, if not a greater degree of cold was obſerved in *Sweden* in 1760†; and we ſhall ſee preſently that a cold even greater than what is here mentioned, has been experienced in other places of Siberia, as well as at Jeneſeiſk.

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* In the treatiſe (Novi Commen. Petrop. Tom. XI.) from which this account is principally extracted, the degrees of heat and cold are eſtimated upon the ſcale of De Liſle's thermometer; but Fahrenheit's being more known in England, I have every where ſubſtituted the corresponding degrees of Fahrenheit's ſcale in the place of the other.

Fahrenheit in 1729 had tried what degree of artificial cold he could produce, by diſſolving pounded *ice* in ſtrong *acid of nitre*; and he was very much ſurpriſed at the event of his experiments, for the quickſilver ſunk to 72 degrees below the freezing point. Boerhaave calls this diſcovery a thing incredible before, and aſks with aſtoniſhment, what mortal could ever have thought of it? Nature, ſays he, had never produced a degree of cold greater than 32 degrees below freezing; and all animals and vegetables expoſed to ſuch a ſeverity of cold inſtantly periſhed *. In this obſervation Boerhaave was certainly miſtaken; for both animals and vegetables can exiſt in degrees of cold which are far ſuperior even to the utmoſt artificial cold which Fahrenheit produced. Several philoſophers have, at different times, repeated Fahrenheit's experiment, but without being able to produce a greater degree of cold than he had done.

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† Novi Comm. Petrop. Tom. VI. p. 39. Sum. Diſ.

Profeſſor Braun, at laſt, on the 14th of December, in the year before

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* Boerh. Chem. Vol. I. p. 162.

fore mentioned, began his experiments, with no other view than that of producing a greater degree of cold than any perſon had done before him; for he rightly conjectured, that the greater the degree of *natural* cold prevailing in the air, the greater would be that of the *artificial* cold. With this deſign he followed, in his firſt attempts, the proceſs of Fahrenheit, pouring the acid of nitre on powdered ice; and he ſucceeded to his wiſhes, having made the mercury ſink to 100 degrees below the freezing point. With hopes of producing a ſtill more remarkable cold, he continued his experiments; in the courſe of which, having uſed all his powdered ice, he ſubſtituted ſnow in its ſtead, and to his infinite ſurprize and ſatisfaction, he found the mercury had deſcended to 384 degrees below freezing. Suſpecting that his thermometer was broken, he took it out of the mixture, and found it uninjured; but he was beyond meaſure aſtoniſhed at ſeeing the quickſilver remain for ſome time immoveable in the tube: it did not begin to aſcend till it had ſtood above 12 minutes in a warm room. He communicated this diſcovery to the Academy at Peterſburgh, on the 17th of the ſame month, and ſtated the congelation of quickſilver as a probable truth; for he had concluded it to be frozen, from its remaining for ſo long a time immoveable in a warm air. In a few days he repeated his experiments, and purpoſely breaking the bulbs of ſeveral thermometers, he obſerved the mercury to be congealed in them all. This *congealed mercury* reſembled the moſt poliſhed ſilver in luſtre; was in ſound and conſiſtency like lead; for he hammered it, and cut it with a knife, before the heat of the atmoſphere reduced it to its former fluid ſtate. This wonderful diſcovery excited the attention of his colleagues in the Academy; his experiments were ſucceſsfully repeated by ſeveral of them; and it was further obſerved, that ſolid mercury ſunk in fluid mercury, after the manner of metallic ſubſtances in general.

The congelation of quickſilver, notwithſtanding the accurate account given of it by Braun, and the many eye-witneſſes of the fact, has been queſtioned by counſellor Lehman of Peterſburgh. According to his obſervation, “ the mercury employed by profeſſor Braun in his experiments, was diſtilled in the common way, through water, and the water only was frozen, and not the mercury itſelf; but having employed mercury diſtilled without water, and carefully purified from all watery particles, the mercury would not congeal, although common mercury did freeze when ſet in ſnow mixed with ſpirit of nitre, or ſpirit of ſal ammoniac*.” In reliance upon the juſtneſs of this obſervation, it has been affirmed that mercury “ is a ſemi-metal, which continues fluid in the moſt intenſe freezing, either natural or artificial, or when both are combined." I do not think this objection of counſellor Lehman of much weight, when put in competition with the great number of experiments which Braun appears to have made with accuracy, and related with fidelity. He himſelf hints at this objection, in the ſupplement which he publiſhed to the account of his diſcovery; but he does not formally refute it, as not thinking it of ſufficient conſequence *. The vapour of diſtilled mercury is indeed generally condenſed in water; but the mercury is afterwards ſtrained through leather, and otherwiſe cleanſed;

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* Counſellor Lehman's Obſervations, quoted by Dr. Forſter, in his Introduction to Mineralogy, 1768. p. 32.

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* Cogitarunt quidam mercurium forſitan vel ob impuritatem, vel ob admixtam mercurio aquam congelari, ſed hæc hypotheſis quam quidam ſumſerant, eſt falſiſſima, omnem in corporibus fieri congelationem ob aquam contentam. Novi Com. Petro. Tom. XI. p. 307.

cleanſed; ſo that I do not apprehend that it contains any water, eſpecially that which is uſed in thermometers; for in making of thermometers, the mercury is expoſed to a great heat, which would effectually diſſipate any particles of water, if any were left adhering to it.

The author of this fine diſcovery has made many experiments, in order to determine what is the ſmalleſt degree of natural cold which is requiſite to make the congelation of quickſilver by an artificial cold, ariſing from the mixture of acid of nitre and ſnow, ſucceed; and he is of opinion, that the degree of natural cold ought not to be leſs than 30 degrees below the freezing point, to make the congelation begin; and that it ought to be 42 degrees below freezing, to make the congelation complete. It ſeems, if we may rely upon theſe experiments, that we can have very few opportunities of attempting on rational grounds to freeze quickſilver, by means of ſnow and acid of nitre; for it very rarely happens that the natural cold in England is 30 degrees below the freezing point, at leaſt near the ſurface of the earth. This reſtriction is added on account of ſome obſervations which are ſaid to have been made at *Glaſgow*, in January 1780. On the 14th of that month, at ſix o'clock in the morning, a thermometer placed upon the ſnow in the obſervatory park, ſtood at 55 degrees below freezing, whilſt one laid upon the ſnow near the ſurface of the earth, was only

18 degrees below freezing. This difference probably proceeds from hence, that the body of the earth warms the air which is contiguous to it, and thus counteracts the cold, which may be accidentally generated in the atmoſphere, more powerfully near its ſurface, than at any great height above it. It would be worth while to obſerve the temperature of the air, at the bottom and at the top of the Monument, or any other high building in the form of an obeliſk, at all ſeaſons of the year, eſpecially in winter time, as greater degrees of cold may probably prevail, from the fall of ſnow and other cauſes in the air, at the top of an high building than at the bottom, eſpecially if the building tapers up into a point, ſo as not to

afford a great maſs of matter to heat the ambient air.

The preciſe degree of cold requiſite to freeze mercury, cannot be aſcertained on account of the ſudden and irregular contractions which it is obſerved to ſuffer, juſt before it begins to be ſolid; it continues to deſcend, after the part contiguous to the bulb of the thermometer begins to freeze; but probably, not leſs than 600 degrees below freezing, are requiſite to congeal it wholly. It is remarkable, that oil of ſaſafras wood, of chamomile flowers, the liquor which remains from the boiling of ſea ſalt, and ſeveral other fluids continued uncongealed, in the ſame degree of cold in which mercury was frozen.

Since the diſcovery of the congelation of quickſilver made by profeſſor Braun, philoſophers have been very attentive, in many places, to effect the ſame thing by the ſame artificial means; and they have ſucceeded in ſome places, particularly at Albany fort in Hudſon's Bay, where quickſilver was frozen by Mr. Hutchins on the 19th of January, 1775, the cold of the air then being 60 degrees below the freezing point. In this account it is obſerved, that the ſtandard thermometer, when taken out of the mixture of acid of nitre and ſnow, fell 10 degrees lower than when the bulb was immerſed in the mixture. A ſimilar phenomenon had been obſerved by profeſſor Braun more than once; and he accounts for it from the acids continuing to diſſolve the ſnow adhering to the thermometer. —May it not proceed from the quickneſs with which the moiſture adhering to the bulb of the thermometer is evaporated, in conſequence of the great warmth of the air when compared with the coldneſs of the moiſture*? The Ruſſians being more favourably ſituated than moſt other philoſophers for making experiments on the effects of cold, it is from them that we muſt expect the further proſecution of this ſubject; I will therefore lay before the reader, an account of the congelation of quickſilver, by the *natural* coldneſs of the atmoſphere, which prevailed at *Kraſnoyarſk*, in the ſouthern part of the province of *Tobolſk:* the account is tranſlated from M. *Pallas'* tour through Siberia, Vol. IV. Part iii. 1763.

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* Philo. Tran. 1776, p. 174 & 590.

" The winter begun this year very early, and was felt with uncommon ſeverity in the month of December. On the 6th and 7th of that month, there was the hardeſt froſt that I have ever obſerved in Siberia; the air was calm, and as it were thickened; ſo that in a quite clear ſky, the ſun was ſeen as through a fog. On the ſixth in the morning, I obſerved my thermometer, which had been carefully made, but was not graduated above 102 degrees below freezing; the quickſilver was ſunk into the bulb, except ſome ſmall pieces which were *clodded* together, and ſtuck in the ſtem: this was an accident which I had never experienced with the ſame thermometer, though I had uſed it eight years. Upon carrying the thermometer into a warm room, the clodded pieces fell immediately into the bulb, but the quickſilver did not begin to aſcend till near a minute after. I repeated this experiment ſeveral times with the ſame ſucceſs, there remaining in the tube ſometimes only one, ſometimes ſeveral little pieces of *frozen quickſilver.* When the quickſilver in the bulb was warmed by the application of a finger, it preſently roſe; and it was plainly ſeen, that the part which was frozen in the ſtem reſiſted the riſe of the quickſilver a conſiderable time, and was at laſt thruſt upwards, aſcending with a ſort of violence. I expoſed to the cold about a quarter of a pound of quickſilver in an open veſſel; the quickſilver had been cleanſed as much as poſſible by vinegar and leather, and it was well dried: in leſs than an hour its ſurface was frozen, and in ſome minutes after it was all condenſed by the natural cold into a ſoft ſubſtance like pewter. When the inner part was yet in a fluid ſtate, the ſurface being broken, was wrinkled in ſome places, but the greateſt part remained pretty even in freezing, as was the caſe alſo with a larger quantity of quickſilver, which was frozen upon another occaſion. The frozen matter of quickſilver was more flexible than lead, but more brittle than pewter, and when hammered into thin plates, it ſeemed ſomewhat granulated; but if the hammer was not perfectly cooled, then the quickſilver glided from it in drops; the ſame happened if it was touched by the finger. In a warm room the quickſilver thawed like wax over the fire, and did not melt all at once. If the frozen maſs was broken in the cold, the pieces clung together, and ſtuck to the ſides of the veſſel wherein they were placed. Though the froſt towards the night ſeemed to abate a little, yet the frozen quickſilver remained unaltered, and the experiment with the thermometer could ſtill be repeated. On the 7th of December I had, during the whole day, occaſion to make the ſame remarks; but ſome hours after ſunſetting, there came on a north-weſt wind, which raiſed the thermometer to 78 degrees below freezing, when the quickſilver begun to diſſolve. Shortly after this, I was favoured with an account from M. Lieutenant General *de Bril*, Governor of *Irkuzk*, that in the ſame town at 4 o'clock in the morning of the 9th of December, the mercury had been found faſt frozen, both in the thermometer and barometer, both of which had been made by profeſſor Laxman when he reſided in Siberia. It ſtood in the barometer 27 inches 7 lines, and the upper five lines were quite broken, but it was liquid again at 11 in the forenoon. The thermometer was clodded at 76 degrees below freezing; and under the 91ſt degree below freezing there was an empty ſpace of near 11 degrees. Towards 11 o'clock all was gone into the globe, and at one o'clock when it was again come into motion, it ſhewed 124 degrees below freezing."

From theſe diſcoveries of the Ruſſians we are fully authorized in conſidering quickſilver as a metal, which requires a greater degree of cold to keep it in a ſolid ſtate than is ordinarily met with upon the ſurface of the earth: gold, and ſilver, and iron, if carried nearer to the ſun, would be perpetually fluid; and quickſilver if removed further from it, would be perpetually ſolid; nay, it may be fairly doubted, I think, whether there may not be elevated places upon the ſurface of the earth cold enough to keep quickſilver in a ſolid ſtate, at leaſt during the greateſt ſeverity of winter.

ESSAY VIII.

Of the manner of making Saltpetre in Europe, and of its generation.

SALTPETRE enters in a large proportion into the compoſition of gunpowder ; hence, after the diſcovery of gunpowder, all the ſtates of Europe were eager in their endeavours to amaſs large quantities of ſaltpetre, and ſtudiouſly ſought out various methods of preparing it ; for ſaltpetre is by many looked upon as the production of art rather than of nature, Gunpowder was very probably made in *England* ſo early as the year 1417. In *Henry* V.'s directions for equipping his fleet with all requiſites, under the general name *ſtuffura*, we find mention made of *Carbonarii*, and of *viginti piparum de pulvere de carbonibus ſalicis* *: theſe twenty pipes of willow-coal powder, could be for no other purpoſe, one would think, than for the making of gunpowder, if gunpowder itſelf did not come under that denomination. Three years before this, a proclamation had been iſſued, forbidding the exportation of gunpowder; and, in thoſe early ages of commerce, it may be thought unlikely that gunpowder would be firſt imported into England, and then exported again. Hollingſhed in his

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* Rymer's Fœder. Tom. XI. p. 543.

Chronicle, ſpeaks of the capture of two French veſſels in 1386, with a great quantity of gunpowder, which, he ſays, was more worth than all the reſt of the cargo; but had no gunpowder been then made in England, it would have been natural for him to have mentioned that circumſtance. This, however, is mere conjecture, and a more diligent ſearch into antiquity may, perhaps, ſhew it to be ill founded. There is a diverſity of teſtimony on this ſubject; one author* aſſerting, that Queen Elizabeth was the firſt of our princes who cauſed gunpowder to be made in England; another † informing us, that a houſe near the Tower, in which gunpowder was made, was blown up in the reign of Edward the Sixth, and fifteen gunpowder-makers ſlain by the accident. But, whenever gunpowder was firſt made in England, it is not without reaſon, that we ſuppoſe it to have been made of ſaltpetre manufactured in England; ſince it is not at all likely that any foreign power would permit the exportation of ſo important, and, at that period, ſo ſcarce a commodity.

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* Baker's Chron. p. 399. Edit. 1696.

† Hollingſhed's Chron. year 1552.

Before ſuch large quantities of ſaltpetre were imported from the Eaſt-Indies, the manufacturing of it in England was much attended to; though it appears, from a proclamation of Charles the Firſt, in the year 1627, that the ſaltpetre-makers were never able to furniſh the realm with one-third part of the ſaltpetre requiſite, eſpecially in time of war.

This proclamation was iſſued in 1627, in conſequence of a patent granted, in the year 1625, to Sir John Brooke and Thomas Ruſſel, for making ſaltpetre by a new invention *. In this new invention, great uſe was made of all ſorts of urine; for the proclamation orders all perſons to ſave the urine of their families, and as much as they could of that of their cattle, to be fetched away, by the patentees or their aſſigns, once in twenty-four hours in the ſummer, and in forty eight hours in the winter ſeaſon. This royal proclamation was no ſmall inconvenience to the ſubject; but it was not ſo great a one as that, by which the ſaltpetre makers were permitted to dig up the floors of all dove-houſes, ſtables, &c. the proprietors

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* Rymer's Fœd. Tom. XVIII. p. 813.

prietors being at the ſame time prohibited from the laying of ſuch floors with any thing but mellow earth. To this grievance all perſons had been ſubjected by a proclamation in 1625, which was revived in its chief extent in 1634, the new invention not having anſwered the purpoſe for which the patent had been granted; and it was not till the year 1656, that an act of parliament paſſed, forbidding the ſaltpetre makers to dig in houſes or lands, without leave of the owners.

As in England the earth impregnated with the dung of pigeons, the urine of cattle, &c. was formerly ſuppoſed to belong to the crown; ſo in France, the rubbiſh of all old houſes, the mellow earth of ſtables, cellars, &c. does at preſent belong to the king. In the dominions of the king of Pruſſia, and in many parts of Germany, the inhabitants are obliged to build mud walls of any fat earth mixed with ſtraw; and theſe walls, in a longer or ſhorter time, according to the quality of the materials of which they are built, and the ſituation in which they are placed, become impregnated with ſaltpetre.

There are a great many materials from which ſaltpetre may be made; in general, all animal and vegetable ſubſtances, when mixed with limeſtone earths, or marles of different ſorts, in ſuch proportion as to excite a putrefaction in the maſs, are proper for this end. The parts of animals, without any addition of earth, are ſaid to yield ſaltpetre by putrefaction; urine ſlightly putrified gives ſaltpetre in a ſmall quantity; being fully putrified it yields it more abundantly *. Kunckel took freſh blood, and left it to putrify in a warm place till it was reduced to earth; he obtained, by this means, above five pounds of ſaltpetre from one hundred pounds of blood †. If this experiment may be generally relied on, it might, perhaps, be worth while to extract the ſaltpetre from the earth remaining in the blood and garbage holes of ſlaughter-houſes. The method of extracting ſaltpetre from the earths in which it is generated, is much the ſame in all countries. It conſiſts in pouring water upon the earths, to diſſolve all the ſalt, of whatever kind, which is contained in them; in paſſing this water through wood

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* Junck. Chem. Vol. II. p. 296.

† Id. p. 235.

wood aſhes, in order to ſupply the unformed parts of the ſaltpetre with a proper alkaline baſis, and in evaporating the ſolution, till it be of a proper ſtrength to ſhoot into cryſtals. The ſaltpetre obtained by this firſt cryſtallization, is ſeldom pure enough for the purpoſes of making gunpowder, or of medicine *.

I do not know that we have at preſent any ſaltpetre works eſtabliſhed in England. There have been many projects propoſed for making it, both in the laſt and preſent century,

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* The reader who wiſhes to know more of the manner of making ſaltpetre, may conſult a very good paper of Mr. Henſhaw's, in Biſhop Sprat's Hiſtory of the Royal Society, p. 260. or Newman's Chemiſtry, publiſhed by Lewis, p. 197. or Glauber's Proſperity of Germany, or Clarke's Nat. Hiſt. of Saltpetre: the manner of making it in Podolia is deſcribed in Philoſ. Tranſ. 1763.

tury, but they have all ended more to the diſadvantage than the emolument of the undertakers. The Society for the Encouragement of Arts and Manufactures in vain propoſed premiums for the making of ſaltpetre, from the year 1756 to 1764 *: theſe premiums were never claimed, and a ſaltpetre work which was, about that time, eſtabliſhed at the expence of above ſix thouſand pounds, was at laſt abandoned; the proprietors having been experimentally convinced, that they could not afford to ſell their ſaltpetre for leſs than four times the price of that imported from India. The reaſon of this conſtant failure in all attempts to make ſaltpetre with profit in England, may be attributed partly

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* Doſſie's Memoirs of Agriculture, Vol. I. p. 197.

partly to the nature of the climate, which probably does not generate ſaltpetre ſo abundantly as ſome other climates do; but principally, it is apprehended, to the dearneſs of the wood aſhes generally uſed in preparing this ſubſtance, and to the high price of the labour which muſt be employed in collecting and manufacturing the materials.

How far wood aſhes are in all caſes neceſſary for the extraction of ſaltpetre from the earths containing it, may be much queſtioned from the reſult of the following experiment.

From an old barn, belonging to the Dean and Chapter at *Ely*, I took ſome decayed mortar, which was full of thoſe ſaline ſhoots frequently ſeen on old walls, and boiled it in a proper quantity of water. The water being filtered and evaporated, afforded in great plenty fine, well-formed cryſtals of ſaltpetre: the cryſtals were taken out and dried, and the remaining part of the ſolution was again evaporated, and it again yielded very good ſaltpetre: but I could not obſerve, that there was any occaſion for wood aſhes to make any part of the ſolution cryſtallize, or that there were formed any cryſtals either of ſea ſalt, or of any other ſalt, except ſaltpetre.

This experiment, which I repeated more than once, contradicts a very generally received opinion, namely, that ſaltpetre cannot be made from the rubbiſh of old buildings, without the concurrence of the ſalt ſeparable from the aſhes of burnt vegetables *.

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* —nullum nitrum a nobis hic in Europa

It cannot be denied, that the vegetable fixed alkali is one of the conſtituent parts of ſaltpetre; but it is contended, that the burning of vegetables is not the only way of procuring that alkali, ſince we ſee, from this experiment, that it was as certainly formed in the mortar as the ſaltpetre itſelf was.

A few years ago, as ſome workmen were digging gravel near *Bury St. Edmund's*, they met with a large ſolid ſubſtance of a white colour, ſurrounded

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ropa natum cognoſci cujus nativitatem non ingreditur *ſal fixus* qui in cineribus lignorum combuſtorum deprehenditur. Boerh. Chem. Vol. II. p. 386. Nature affords no perfect ſaltpetre. — We may be aſſured that cryſtalline nitre, whenceſoever it comes, has been manufactured by art; that art has ſupplied *its alkaline baſis*, and reduced it into a cryſtalline form. Newman's Chem. p. 197.

rounded every way with gravel, and at the diſtance of twelve or fourteen feet from the ſurface. They at firſt miſtook it for a lump of chalk; but upon taſting it, they found it to have the taſte of ſaltpetre. I have a piece of the original lump in my poſſeſſion. It is a ſolid maſs, very hard; when diſſolved and cryſtallized, it affords cryſtals, reſembling in all their properties the pureſt ſaltpetre. Unleſs more care had been taken in examining the ſituation of this lump of ſaltpetre, when it was firſt diſcovered, it may be difficult to account for its production; but it is highly probable, that it was a natural production, and that the aſhes of burnt vegetables had never been employed in its formation. The roots of horſe-radiſh penetrate very deep into the earth; and upon inquiry I found, that horſe-radiſh grew upon the ſurface of the earth where this maſs of ſaltpetre was formed. Whether this plant had contributed to its formation, may be a queſtion worthy the reader's conſideration, ſince we know that many plants, ſuch as borage, fennel, the ſun-flower, and tobacco, yield ſaltpetre.

Another obſervation which may be drawn from what has been advanced, reſpects the nature of thoſe ſaline effloreſcences which were found in the mortar, and are frequently to be met with on old damp walls, and from which the word ſaltpetre, or ſalt of ſtone (*ſal petræ*), ſeems to be derived. Many authors* have affirmed, that the ſalt of theſe ſhoots is the mineral fixed alkali. I have reaſon, from my own experiments on the ſubject, to believe, that the affirmation is true in ſome inſtances; but it muſt not, I apprehend, be generally admitted, ſince we have ſeen that thoſe ſhoots yield, in ſome circumſtances, not the *mineral alkali*, but a perfect *ſaltpetre.*

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* See a Paper of the very ingenious Dr. Brown-

With great diffidence I propoſe it to be conſidered, whether the ſame ſaline ſhoots which in ſome caſes conſtitute the mineral fixed alkali, would not, if left to themſelves on the ſame place where they are produced, be at length converted into ſaltpetre. The operation of nature in

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Brownrig in Philoſ. Tranſ. for 1774. p. 485. — Opus Chym. by Marggraaf, Vol. II. p. 419.—Cronſtedt's Miner. p. 143.

in ſpontaneouſly producing thoſe ſhoots of mineral fixed alkali, is in no reſpect leſs wonderful than the converſion of the fixed alkali itſelf, by a longer proceſs, into ſaltpetre. This conjecture, founded on the different qualities of theſe ſaline ſhoots, and the manner of their being produced, may receive ſome confirmation from the two following facts. "Near the city of *Xen Si* in *China* is a town, about which the land produces three things. One is the ſoap they uſe there, called *Kien*; they know nothing of our's. After it has rained, if the ſun ſhine, there riſe out of the earth certain bladders of thick froth, which are gathered to waſh and whiten linen. The ſecond is *ſaltpetre*; and *common ſalt* the third. Out of twenty pounds of earth, put into a jar, and wrought after their manner, they get twelve pounds of ſalt, and three of ſaltpetre *." It is probable, that the *Kien* here ſpoken of, as ſupplying the place of ſoap, conſiſts in part or wholly of the mineral fixed alkali. " Upon the coaſt of *Coromandel*, in a ſandy ſoil, not far from the ſea, the inhabitants gather every morning, an earth abounding with a natural alkali; of this earth they make a ley, which being ſharpened by quick-lime, they uſe in fixing their colours on their linen cloths. But if the alkali be left undiſturbed upon the place where it is produced, it ſpontaneouſly changes itſelf into ſaltpetre †."

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* Churchill's Coll. of Travels, Vol. I. p. 49.

† —— ſi vero ſuo generationis loco relinquitur

If this ſandy earth was waſhed, common ſalt and ſaltpetre might probably be ſeparated from it, as is done from the Chineſe earth before mentioned, and the two accounts confirm one another. If theſe accounts be

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quitur alcali prædictum, *ſponte in nitrum ſe* tranſmutat. —— Miſcell. Cur. Germ. ann. 9. & 10. p. 460. There is an account in the Philoſophical Tranſactions for 1771. p. 567, of a foſſile alkaline ſalt, found in the country of Tripoli in Barbary, which our callico-printers thought anſwered their purpoſes better than any other ſalt they had ever tried. This obſervation confirms what is ſaid of the uſe of this ſalt found on the coaſt of Coromandel, and teaches us to attribute the excellency of the Eaſt India colours to the nature of the alkali uſed in fixing them. The French dyers uſe an alkali prepared from the burning of tartar and lees of wine: this alkali is of the pureſt kind; and the ſuperiority of their colours over thoſe of moſt other countries, has been attributed to the great purity of the alkali which they uſed. Memoires de Chem. Vol. II. p. 556.

be admitted, they will greatly tend to reconcile the different opinions of chemiſts concerning the nitre or *natron* of the ancients; ſome holding it to have been the mineral fixed alkali, and others eſteeming it the ſame with our ſaltpetre; for it may in fact have been either one or the other, or a mixture of both, according to its age.

It may in the laſt place be remarked, that ſea ſalt does not always accompany ſaltpetre in the earths where it is generated, ſince not a grain of ſea ſalt could be obtained from a large portion of the decayed mortar. From the great quantities of ſea ſalt uſually found in ſaltpetre earths, ſome chemiſts* have conjectured, that ſea ſalt was inſenſibly changed into ſaltpetre; and others have ſuppoſed, that the ſame natural proceſs which produced ſaltpetre, produced alſo ſea ſalt. The fore-mentioned experiment renders this laſt ſuppoſition ſomewhat doubtful; the matter however is not certainly eſtabliſhed either way, and there is great room for further inveſtigation.

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* Baumé Chy. Vol. III. p. 599.

This leads us to the conſideration of a queſtion of very difficult deciſion—how is ſaltpetre generated? I am not aſhamed to own my inability to anſwer this queſtion in a manner ſatisfactory even to myſelf. There are powers in nature in a great meaſure unknown to us, by which the parts of matter are ſubjected to perpetual change, and forced to aſſume arrangements from which new compounds are conſtantly reſulting. The ſweet, bitter, and aromatic juices of vegetables; the blood, bile, milk, urine, fat, and bones of animals, are all of them as different from the ſubſtances from which they are compoſed, as ſaltpetre is from the earth from which it is generated: but the one being a more common proceſs of nature than the other, it does not ſo much aſtoniſh us, or excite our curioſity to account for it. The anſwer of the Spaniard who was aſked if he knew how the ſaltpetre was yearly regenerated in his grounds, ſeems to include all that philoſophy can ſay on the ſubject: "I have two fields; in the one I ſow wheat and it grows; in the other I collect ſaltpetre*."

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* Hiſtoire Nat. de L'Eſpagne, by Bowles, p. 80.

There was a time when the air was looked upon by all chemiſts, as the great ſtorehouſe of ſaltpetre; and the earths in which it was found were ſuppoſed to have attracted it, ready formed, from the air. Inſtead of ſaltpetre in ſubſtance, ſome later philoſophers have ſuppoſed that its acid part only exiſts in the air; and that this acid part, being attracted from the air, unites itſelf with the earths which yield ſaltpetre. Others are of opinion, that the acid of ſaltpetre does not float in the air as a ſubſtance diſtinct from it, but that it is one of the conſtituent parts of the air itſelf; and conſequently, if ſaltpetre be formed by the earths attracting this acid, the air muſt be decompoſed. I know not of any well conducted experiments which are ſo concluſive in favour of this aerial origin of ſaltpetre, as one of Lemery's is againſt it. He put ſome lime into one diſh, ſome ſalt of tartar into another, and a ſaltpetre earth, from which he had extracted the ſalt, into a third. He placed theſe three diſhes in a ſituation open to the acceſs of the air, and ſheltered from the ſun; he let them continue in that ſituation for two years; at the expiration of that term he examined their ſeveral contents, but no ſaltpetre had been generated in any one of them; tho' ſaline ſhoots had been formed on the walls of the place in which they ſtood. He afterwards mixed theſe ſame ſubſtances with animal matters, and after they had ſtood a proper time, they all yielded him ſaltpetre*.

Saltpetre, it is granted, cannot be produced without air; but a ſimple expoſure to the air of the materials in which it is moſt generally found, does not ſeem to be ſufficient for the purpoſe. Air is neceſſary for the commencing and continuing of that inteſtine motion of the parts of vegetable and animal ſubſtances, which is called putrefaction; and I do not know whether the ſame may not be ſaid of ſome minerals: hence, perhaps, it may not be a propoſition far from the truth if we ſhould ſay, that ſaltpetre is never produced in ſubſtances which have not undergone a putrefactive fermentation. Thus

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* Memoires de l' Academie des Scien. a Paris; ann. 1731.

Lemery got ſaltpetre as ſoon as he mixed with his earths animal ſubſtances, which ever tend to putrefaction. Freſh blood contains no ſaltpetre, but Kunckel extracted a large quantity from putrified blood. Freſh urine yields no ſaltpetre, but putrified urine yields it in great abundance, as may be gathered from the patent before mentioned, by which it was ordered to be ſaved for the making of ſaltpetre. Quicklime does not contain a particle of ſaltpetre; a mixture of freſh urine and quicklime, if examined ſoon after it is made, will not yield any; but after being ſuffered to putrify for ſix or ſeven months, very good ſaltpetre may be extracted from it*. All the common proceſſes for making

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* Chymie par M. Baumè, Vol. III. p. 594.

ing ſaltpetre imply the putrefaction of the materials. Now if it be allowed that ſaltpetre is never produced without ſome kind and degree of putrefaction, it may deſerve to be inquired, whether in its mode of generation it has not ſome relation to two other ſubſtances univerſally produced by putrefaction; I mean *fixed air* and *volatile alkali.* Many conjectures, not ſufficiently warranted by experiment to be laid before the reader, preſent themſelves on this head: one experiment, however, I will mention, eſpecially as it is generally adduced by chemical writers in ſupport of their theories concerning the origin and nature of the acid of ſaltpetre. When ſaltpetre and charcoal in powder are thrown together upon a fire, or any red-hot ſubſtance, the ſaltpetre is ſuddenly exploded, with a noiſe which is uſually called *detonation*; much air is ſet at liberty; there ariſes a very copious condenſable fume, and there remains, when the detonation is finiſhed, a *fixed alkali*; that is, there remains one of the conſtituent parts of ſaltpetre; the other part, namely, the acid, is diſperſed with the fume. This condenſable fume has been collected, and it is ſaid to contain nothing but water, mixed accidentally with a little fixed alkali, which is ſuppoſed to have proceeded from the alkaline baſis of the nitre [*]. The liquor thus collected, is called the *clyſſus* of nitre. I have frequently collected this liquor, and always found that it abounded with *volatile alkali*.

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[*] Diction. of Chem. Art. *Clyſſus*.

alkali. This volatile alkali may be rendered viſible in a concrete form, by diſtilling the clyſſus with a gentle heat. Is the nitrous acid formed from an union of fixed air with volatile alkali by means of putrefaction? What is fixed air, and what is volatile alkali, and how are they produced, are queſtions which want an explanation juſt as much as what is the acid of ſaltpetre, and how is it produced?

ESSAY IX.

Of the Manner of making Saltpetre in the Eaſt Indies.

THE reader will not be diſpleaſed with ſeeing ſome of the beſt accounts which I have met with in books on this ſubject, in the words of the ſeveral authors.

"There is alſo a great deal of ſaltpetre vended at *Suratte*, which is made at *Aſmer*, 60 leagues from *Agra*, out of the fatteſt ground, after it has lain fallow a conſiderable time. They dig certain trenches, which, after they have filled with ſalt earth, they let in as much water as is ſufficient to reduce it to the conſiſtency of broth; and to ſoak it the better, they frequently tread it with their feet: when they judge the water has diſſolved all the ſaline ſubſtance that was in the earth, they draw up the water into another trench, where in ſome time it thickens, when they boil it like ſalt, ſcumming it continually, and afterwards put it into earthen pots, where the dregs being ſettled to the bottom, they take it out again, and dry it to a hard ſubſtance in the ſun *."

" The manner in which nitre is originally obtained in the Eaſt Indies,

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* Harris's Collection of Voyages, Vol. II. p. 128.

dies, is (as I have it on the authority of a perſon of unqueſtionable veracity, who made it his particular buſineſs to procure a juſt information) according to the following account. There is a very tall kind of graſs growing in the country where the nitre is produced; which being burnt cuſtomarily in the autumn, forms beds of very large extent, covered with ſuch ſalts and earths, reſulting from the incineration, as are the moſt proper matrices for the formation of the nitre. Theſe, lying all the winter on the ſides of hills expoſed to the winds, conſequently collect the nitrous ſpirit from the air, in the ſame manner as when ſpread by art with that intent; and produce great quantities of nitre. After this a rainy ſeaſon enſues, which waſhes the ſalt down into the vallies; where the ſolution, partly abſorbed by the earth, and partly flowing above it, is expoſed to the heat of the ſun, that makes an evaporation of the humidity, and leaves the ſalt in a dry ſtate, either commixt with the earth, or on the ſurface of it; and this is ſometimes artificially aſſiſted, by turning the rills of water as they deſcend from the higher grounds by proper tanks, into places where the abſorption of it by the ground is prevented; and where therefore the fluid drying away by inſolation, produces a ſtrong ſolution of the nitre; which being taken out and purified in that ſtate, is afterwards reduced into a cryſtalline form by evaporation [*]."

"Salt,

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[*] Doſſie's Inſtitutes of Chem. Vol. II. p. 321.

" Saltpetre is likewiſe the produce of *Patna.* It is extracted from a clay, which is either black, whitiſh, or red. The manner of refining it, is by digging a large pit, in which this nitrous earth is depoſited, and diluted with a quantity of water, which is kept ſtirred till it comes to a conſiſtency. The water having drawn out all the ſalts, and the groſſer parts ſubſiding at the bottom, the more fluid particles are taken out and put into another pit not ſo large as the former. This ſubſtance having undergone a ſecond purification, the clear water that ſwims on the top, and is totally impregnated with nitre, is taken off and boiled in caldrons; it is ſcummed while it is boiling, and in a few hours a nitrous ſalt is obtained infinitely ſuperior to any that is found elſewhere ‡. The Europeans export about ten millions of pounds for the uſe of their ſettlements in Aſia, or for home conſumption in their reſpective countries. It is bought upon the ſpot for three ſols (1d. $\frac{1}{2}$) a pound at the moſt, and is ſold again to us for ten (5d.) at the leaſt ‖.

By the enquiries which I have had an opportunity of making, from gentlemen who had long reſided in the Eaſt Indies, I can only learn, that there are certain earths naturally impregnated with ſaltpetre, and that the inhabitants throw up theſe earths in little heaps, reſembling the heaps in which lime is uſually ſcattered over a field before it is ſpread; and at a proper ſeaſon they extract the ſaltpetre, and cryſtallize it without making any uſe of the aſhes of burnt vegetables. This method of making ſaltpetre is much the ſame with that practiſed in Egypt, as deſcribed by an author near an hundred years ago. The ſurface of the earth, we are told, where ſaltpetre is found, is in ſome places covered with a whitiſh cruſt; in others the ſalt is diſcovered by the taſte of the earth. This earth is dug up, and being paſſed through a ſieve, they ſteep it in water, and then boil the water till the ſalt falls to the bottom. All the gunpowder made in Egypt was formerly made of this ſaltpetre*; which ſhews the ſalt thus procured to have been not the mineral alkali, but a true ſaltpetre.

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‡ I am ignorant of the particulars in which the Eaſt India nitre excels that made in different parts of Europe.

‖ Hiſtory of European Settlements in the Eaſt and Weſt Indies. Eng. Tranſ. Vol. I. p. 340.

That this is a very poſſible method of making ſaltpetre is certain, not only from the experiment with the old mortar mentioned in the preceding Eſſay, but from what is conſtantly practiſed in Spain, where they extract large quantities of ſaltpetre from earths naturally impregnated with it, without having recourſe to vegetable aſhes. A third part of the uncultivated lands in Spain, is ſaid to abound with ſaltpetre ready formed. Theſe lands, where they are wrought for ſaltpetre, are turned over two or three times in the winter, and ſpring; and in Auguſt they throw the earth in heaps, and extract the ſaltpetre by pouring water on the earth, put into proper veſſels, and cryſtallizing the ſolution. The earth, after the extraction of the ſaltpetre, is ſpread on the ſame ground from which it was taken, and at the expiration of twelve months it again becomes impregnated with ſaltpetre, and the ſame earths have for time immemorial annually produced the ſame quantity of ſaltpetre *. This Spaniſh earth reſembles the Chineſe earth, mentioned in the laſt Eſſay, in containing a large portion of ſea ſalt, for they obtain from twenty to forty

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* Toute la poudre qu' on fait en Egypt n' eſt fait que de ce nitre, qui eſt le vray ſalpetre. Journ. de Sçavans 1685.

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* Hiſt. Nat. de l' Eſpag. p. 79. French Tranſ. 1778.

pounds of common ſalt from one hundred pounds of the earth: the crude ſaltpetre alſo as brought from the Indies, is greatly polluted with common ſalt. —— Is the *common ſalt* in the Spaniſh earth, annually *regenerated* as well as the *ſaltpetre?*

The lands in Spain, ſays the author of its Natural Hiſtory, if properly managed, would ſupply all Europe with ſaltpetre to the end of the world. In this circumſtance Spain is more fortunate than England, as we are obliged to rely upon our importation from the Eaſt Indies for all the ſaltpetre we uſe. Spain however has not yet been able, or willing to furniſh from its lands, ſaltpetre enough for its own conſumption; ſince it is obliged, occaſionally, to have recourſe to an importation of that commodity from this kingdom.

The Eaſt India company had their firſt charter granted in 1600: in the year 1628 they publiſhed their petition and remonſtrance to the Houſe of Commons. From this tract it appears, that they had good quantity of ſaltpetre then in ſtore, and that they weekly made about thirty barrels of gunpowder at their own powder mills, from ſuch refined ſaltpetre as they brought from the Indies. By their charter, granted in 1693, they were bound annually to ſupply government with 500 tons of ſaltpetre at 38*l.* 10*s.* a ton in time of peace, and at 45*l.* in time of war.

The following tables were extracted from the cuſtom-houſe books, by a perſon on whoſe accuracy I could depend.

Saltpetre imported annually into England for ſeven years ending at Chriſtmas 1769.

	C.	q	lb.
From Xtmas 1762 to Xt. 1763—	42580	2	26
1764—	22692	3	6
1765—	35399	3	7
1766—	41313	0	0
1767—	37424	2	22
1768—	33840	3	26
1769—	34437	3	0
Total imported in 7 years —	247689	3	3

This quantity gives an annual medium of 3963036 lb *.

About

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* The Dutch Eaſt India fleet in 1709, imported 2175370lb. of ſaltpetre; (Schelhamer de nitro. p. 82;) yet notwithſtanding the great quantities of ſaltpetre which are annually brought into Europe from the Eaſt Indies, it is reckoned that two-thirds of the whole produce of that commodity are ſent into

Saltpetre exported from England, from Chriſtmas 1762 to Chriſtmas 1769.

Exported to	1763.			1764.			1765.			1766.			1767.			1768.			1769.		
	C.	q.	lb.	C.	q.	lb.	C.	q.	lb.	C.	q.	lb.	C.	q.	lb.	C.	q.	lb.	C.	q.	lb.
Denmark and Norway	292	0	3	780	3	8	276	2	10	588	1	18	97	1	21	......			634	2	0
Eaſt Country	123	3	15	701	1	27	......			......			......			......			......		
Flanders	11	3	9	147	1	19	125	0	22	391	1	16	603	0	4	115	0	15	103	0	14
France	20	0	0	......			......			......			473	1	7	......			......		
Germany	202	2	0	642	0	14	254	2	18	91	3	21	119	3	17	......			1,761	0	11
Holland	2,216	1	7	11,518	3	10	4,864	0	0	3,485	1	3	1,742	1	12	61	0	13	......		
Ireland	389	3	6	329	0	0	419	1	14	570	1	18	1,296	2	0	538	0	9	1,609	3	2
Italy	......			......			......			......			......			......			59	0	27
Portugal	......			8	3	4	2,018	2	0	84	1	0	82	0	0	70	1	0	20	0	0
Spain	3,603	2	6	......			......			247	2	10	1	1	4	......			......		
Streights	243	2	16	1,976	2	12	......			......			......			......			......		
Turkey	......			......			......			......			......			......			60	0	8
Antigua	......			......			......			0	1	8	......			0	2	0	......		
Barbadoes	1	1	11	7	2	0	1	3	12	4	3	18	4	0	11	4	0	21	7	0	22
Canada	22	0	0	0	2	14	......			......			0	2	24	......			2	1	10
Carolina	50	1	10	28	0	16	39	1	0	27	0	7	22	0	10	25	2	6	34	3	11
Georgia	4	2	0	......			6	1	2	3	0	0	1	3	7	5	2	0	12	3	0
Florida	......			1	0	0	......			......			......			0	2	0	......		
Jamaica	......			3	3	14	1	2	18	1	3	19	3	0	12	2	0	20	2	3	16
New England	15	3	12	21	3	0	13	0	0	8	2	14	20	3	0	44	2	8	22	2	7
New York	6	3	0	2	2	11	3	1	0	6	0	20	7	2	7	12	3	0	6	2	19
Nova Scotia	......			......			......			......			0	2	4	......			......		
Pennſylvania	10	3	14	21	1	0	8	1	0	52	2	8	23	3	17	49	1	20	37	0	0
St. Chriſtopher's	......			......			......			......			1	1	2	......			......		
Virginia and Maryland	6	3	0	9	3	17	20	2	2	25	3	6	47	2	12	43	0	2	48	2	10
Totals	7,221	3	25	16,201	3	8	8,052	1	14	5,589	2	18	4,549	1	3	972	3	2	4,422	2	17

Total exported in 7 years—47,010 C. 2 q. 3 lb. This quantity gives an annual medium of 752,168 lb.

About the ſame period that the government of England bargained with the Eaſt India company for an annual ſupply of ſaltpetre, a much larger quantity was made in France; an author of good credit * informing us that in the year 1691 the ſaltpetre which was made in the ſeveral diſtricts of that kingdom, amounted to — 3647767½ pounds. This is a vaſt quantity, being nearly equal to the average quantity annually imported by our Eaſt India company. The French very wiſely keep up their eſtabliſhments for the making of ſaltpetre; the revolutions which have formerly taken place in India, render it not improbable, that ſimilar

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into China, and other parts of Aſia, to be uſed in fire-works.

* See Memoires d' Artillerie par Sr. Surirez, Tom. II. p. 104. Amſter. 1702.

ones may take place again; and England would feel the diſtreſs which would attend the non-importation of ſaltpetre from the Eaſt Indies, more ſenſibly than any other ſtate in Europe. This danger has not been adverted to by any Miniſter; but if the prevention of it ſhould ever engage the attention of the legiſlature, the methods of making ſaltpetre which are followed in France, would deſerve to be conſidered. For my own part I can have no doubt, that a plan might be contrived for the making of ſaltpetre in every county of this kingdom, by the very moderate labour of thoſe, whoſe idleneſs is at preſent a burden to themſelves, and a reproach to the police of the community, the *paupers* of the ſeveral pariſhes.

ESSAY X.

Of the Time when Gunpowder was diſcovered.

THE hiſtory of the diſcovery of gunpowder is involved in much obſcurity; the moſt ancient authors differing from each other in their accounts of this matter, and many of them confounding two diſtinct inquiries; — the diſcovery of the compoſition of gunpowder; —and the diſcovery of the means of applying it to the purpoſes of war.

Father *Kircher** affirms, that without controverſy we ought to attribute the invention of gunpowder to *Barthold Schwartz*, or Barthold the Black, a monk of Goſlar in Germany, and a profound alchemiſt. This man having mixed together, with a medical view, *nitre*, *ſulphur*, and *charcoal*, a ſpark accidentally fell upon the mixture, blew up the pot in which it was contained, and cauſed a dreadful exploſion. The monk, aſtoniſhed at the event, made ſeveral repetitions of his experiment, and thereby fully diſcovered the nature of gunpowder, in the year 1354. Kircher gives us alſo, out of a very old German book which he profeſſes to have read, a monkiſh account of the firſt uſe which Schwartz made of his gunpowder; he employed it to frighten ſome robbers from their haunts in the woods.

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* Kirch. Mun. Sub. p. 487.

Sebaſtian Munſter ſays, that he was well informed by a very eminent phyſician, that the Danes uſed guns in naval engagements in the year 1354, and that a chemiſt called Schwartz was the firſt inventor of them[†]. *Pontanus*, the Daniſh hiſtorian, accedes to this opinion.

Polydore Vergil, who died in the year 1555, attributes the diſcovery of gunpowder to ſome very ignoble German, whoſe name he wiſhes might never be handed down to poſterity. He further informs us, that this German invented alſo an iron tube, and taught the Venetians the uſe of guns in the year 1380 *.

[†] Achilles Gaſſarus medicinæ doctor, et hiſtoriographus, diligentiſſime ſcripſit mihi, Bombardas anno Chriſti 1354, in uſu apud mare Danicum fuiſſe, primumque inventorem et autorem extitiſſe chymiſtam quendam nomine Bartholdum Schwartzum monachum. Munſter. Coſmogr. Univ. Lib. 3. C. 174.

This is the common account of the diſcovery of gunpowder; its truth however is rendered doubtful by what follows.

The battle of *Creſſy* was fought in the year 1346; and an hiſtorian who lived at that time is quoted by *Spondanus* as affirming, that the Engliſh greatly increaſed the confuſion the French had been thrown into, by diſcharging upon them from their cannon hot iron bullets †. Three years before the battle of Creſſy, the Moors were beſieged by the Spaniards in the city of *Algeziras*; and we learn from *Mariana*, the Spaniſh hiſtorian, " that the beſieged did great harm among the Chriſtians with iron bullets they ſhot:" the ſame author adds, " this is the firſt time we find any mention of gunpowder and ball in our hiſtories *." The *Earls* of *Derby* and *Saliſbury* are mentioned by Mariana as having aſſiſted at the ſiege of Algeziras; and as they returned to England in the latter end of the year 1343, it is not an improbable conjecture, that, having been witneſſes of the havock occaſioned by the Mooriſh fire-arms, they brought the ſecret from Spain to England, and introduced the uſe of artillery into the Engliſh army at the battle of

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* Polyd. Verg. de Inven. Rerum. Lib. II. C. XI.

† Spond. Ann. Eccle. ann. 1346.

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* Mariana's Hiſt. of Spain, Eng. Tranſ.

Creſſy. The uſe of guns in Spain in the year 1343, is proof ſufficient either that Schwartz was not the inventor of gunpowder, or that Kircher and others are miſtaken in fixing his diſcovery ſo late as the year 1354.

There is reaſon, however, to believe, that both gunpowder and guns were known in Germany at leaſt forty years before the period aſſigned by the Spaniſh hiſtorian for their firſt introduction into Spain. In the armoury at *Amberg*, in the Palatinate of *Bavaria*, there is a piece of ordnance, on which is inſcribed the year 1303 †. This is the earlieſt account I have

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† Quam opinionem (of Schwartz being the inventor of gunpowder) generoſiſſimus Stettenius refutat, cum ex eo quod Ambergæ Palatinatûs Superioris in officina armorum reperiatur tormentum militare cui ſit annus 1303 inſcriptus. Acta Erud. 1769. p. 19.

I have yet met with of the certain uſe of gunpowder in war; and it ſeems probable enough, as the *Pope* and the *Duke* of *Bavaria* are thought to have been the firſt princes who made ſaltpetre in Europe [*].

It ought not to be concealed from the reader, that *Camerarius* quotes a Daniſh hiſtorian as relating, that *Chriſtopher*, king of the Danes, was killed in battle by the ſtroke of a gun, in the year 1280 [†]. Upon examining the paſſage quoted by Camerarius [‡], it is only ſaid, that *Chriſtopher*, the ſon of king *Waldemar*, was killed in the beginning of an engagement by a gun, a warlike inſtrument then lately diſcovered. Now it appears*, that Waldemar, Chriſtopher's father, did not ſucceed to the crown of Denmark till the year 1332, and that his ſon was killed in a naval engagement ſeveral years afterwards†, probably about the time aſſigned by Munſter for the firſt uſe of gunpowder in Denmark.

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[*] Clarke's Nat. Hiſt. of Saltpetre.

[†] Cranzius ſcribit Chriſtophorum Danorum regem in prælio bombardæ ictu occiſum anno 1280. Camera. Hor. Subſ. Con. p. 3. 312.

[‡] Cranzius Vandal. Lib. VIII. C. 23.

But we are able, upon good grounds, to carry the diſcovery of gunpowder to a period antecedent to the date of the Amberg piece of ordnance; and it is probable enough, that its compoſition was known long before we read any thing of its uſe in war.

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* Cranzius Daniæ. Lib. VII. C. 32.

† Id. Lib. VII. C. 38.

Roger Bacon died at Oxford in 1292. In the printed copies of the works of this renowned Monk, there are two or three paſſages, from which it may fairly be inferred, that he knew the compoſition of gunpowder *; and a manuſcript copy is ſaid to have been ſeen †, wherein *ſaltpetre*, *ſulphur* and *charcoal* are expreſſly mentioned, as the ingredients of a compoſition which would burn at any diſtance. But though it be allowed, that Bacon was well acquainted with the compoſition of gunpowder, it will not follow, either that he was the firſt diſcoverer of it, or that he knew its application to fire-arms.

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* In omnem diſtantiam quam volumus, poſſumus artificialiter componere ignem comburentem ex ſale *petræ* et *aliis*. R. Bacon de Mirab. Poteſ. Artis et Naturæ. Epiſ. C. VI. — ſed tamen ſalis *petræ Luru vopo vir Can utriet ſulphuris* et ſic facies tonitrum et coruſcationem, ſi ſcias artificium. Id. ib. C. XI. It is very probable, that in the firſt of theſe paſſages, Bacon concealed ſulphur and charcoal under the word *aliis*; and that in the laſt, having mentioned ſaltpetre and ſulphur, he concealed charcoal and the method of mixing the three ingredients, under the barbarous terms, Luru vopo vir can utriet.

† Plott's Nat. Hiſt. of Oxfordſhire.

The Moors, we have ſeen, who had ſettled in Spain, are eſteemed by ſome to have been the firſt perſons who uſed gunpowder in the practice of war; they alſo brought into Europe a great many Arabian books, and introduced a taſte for chemiſtry into different countries, about the time in which Bacon flouriſhed. It is confeſſed, on all hands, that Bacon was no ſtranger to Arabian literature; a great part of his optical diſquiſitions, being evidently borrowed from *Albazen* the *Arab*; and it is not a ſuppoſition wholly void of probability, that he derived his knowledge of the compoſition of gunpowder from the ſame ſource. As to his knowledge of the uſe of it in war, he certainly had ſome idea of it; for he intimates, that cities and armies might be deſtroyed by it in various ways: but it is not equally certain that he had any ſpecific notion of the manner of uſing gunpowder, which unqueſtionably prevailed ſoon after his death.

It is one thing to throw out a conjecture concerning the effects which might be produced by the proper application of a known ſubſtance; another, to deſcribe the means of applying it. There are ſubſtances in nature, from a combination of which it is poſſible to deſtroy a ſhip, or a citadel, or an army, by a ſhower of liquid fire ſpontaneouſly lighted in the air: every perſon who is aware of the dreadful fiery exploſion which attends the mixture of two or three quarts of ſpirit of turpentine with ſtrong acid of nitre, muſt acknowledge the truth of the aſſertion; but the ſimple knowledge of the poſſibility of effecting ſuch a deſtruction, is a very different matter from the knowledge of its practicability; though future ages may, perhaps, invent as many different ways of making theſe ſubſtances unite in the air, ſo as to fall down in drops of fire, as have been invented of making gunpowder, a ſad inſtrument of the deſtruction of our ſpecies ſince the time of Bacon.

From the accounts given of the attempts of *Salmoneus* and *Caligula* to imitate thunder and lightning, ſome have been of opinion that gunpowder was known to the ancients [*]: be that as it may, we cannot heſitate in admitting that it has been long known in various parts of Aſia. It would be uſeleſs to cite a variety of authorities in proof of this point; I will content myſelf with that of Lord Bacon:—“ Certain it is, that ordnance was known in the city of the Oxidrakes in India; and was that which the Macedonians called thunder and lightning, and magick. And it is well known that the uſe of ordnance hath been in China above 2000 years *."

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[*] See Duten's Enquiry into the Diſcoveries of the Moderns, p. 263. Engliſh Tranſlation.

One of the moſt uſeful applications of gunpowder, is in the art of mining. The hammer and metallic wedges were probably the firſt inſtruments which men uſed for the ſplitting of rocks. The application of wooden wedges to the ſame purpoſe, ſeems to have been a more recent diſcovery: it is the property of dry wood to expand itſelf, when wetted with water: miners have had ingenuity enough to avail themſelves of this pro-

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* Bacon's Eſſay on the Viciſſitude of Things.

property, for it is a practice with them to drive wedges of dry wood into the natural or artificial crevices of rocks, and to moiſten the wedges with water. Wood, by imbibing moiſture, ſwells in every dimenſion; and the force of this expanſion is ſufficient, in many caſes, to detach large pieces from the main body of a rock. But the expanſive force of gunpowder is incomparably greater than that of moiſtened wood. There are different accounts of the time when gunpowder was firſt applied to the blaſting of rocks. "*Roſsler* relates that in 1627, the blaſting of mines was brought from *Hungary*, and introduced in the *German* mines: but *Bayer* ſays, that in 1613, it was invented by *Martin Freygold* at *Freiberg* *."

In anſwer to an inquiry which I made concerning the time when blaſting was introduced at the famous copper mine at *Ecton* in *Staffordſhire*, I received the following account from a very able and intelligent perſon. "I can give you a little better information concerning the affair of blaſting. I have known that country where the mine is, above fifty years; and have often ſeen the ſmith's ſhop in which, tradition ſays, the firſt boring auger that had ever been uſed in England was made; and that the firſt ſhot that was ever fired in Derbyſhire or Staffordſhire, was fired in this very copper-mine at Ecton. The inhabitants of Wetton (a village adjoining to the mine) tell me the auger was made by ſome *German* miners, ſent for over by *Prince Rupert* to work this copper mine at Ecton. The Prince (Rapin ſays) came into England in 1636, andwas ordered by the King to leave the kingdom 1645; and though he was afterwards admiral under Charles the Second, it is moſt probable the miners came during his firſt abode in this kingdom. I am very well convinced of the truth of the above tradition, becauſe the fathers of my informers might be very well acquainted with the miners that introduced blaſting among them." In addition to this account I would obſerve, that the manner of ſplitting rocks by gunpowder, as practiſed at *Liege*, was publiſhed by the Royal Society in 1665; and that it was not till about the year 1684, that the miners in Somerſetſhire began to uſe gunpowder [*]. In the year 1668 Prince Rupert was choſen governor of the *Society for the Mines Royal* [†]; and as he lived fourteen years after that appointment, it is not improbable that he might ſend for the German miners in conſequence of his connexion with that ſociety.

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* See Travels through the *Bannat*, &c. by *Baron Born*. Eng. Tranſ. p. 192.

Before the diſcovery of blaſting rocks by gunpowder, it was the cuſtom in our Engliſh mines, as well as in Germany, to ſplit them by wood fires. This method is minutely ly deſcribed by Agricola *, and it is not yet wholly fallen into diſuſe ‡. It is a very ancient mode of mining, being mentioned by Diodorus Siculus, as practiſed in ſome Egyptian mines §: he gives us, in the place here referred to, ſuch a melancholy account of the condition of the poor ſlaves who were employed in thoſe mines, as muſt make the heart of every humane man, who has a rational reſpect for the natural rights of every individual of our ſpecies, ſwell with indignation, and thrill with horror. Would to God, that the clemency of the taſkmaſters in the mines of *Peru*, and in other ſettlements of European *Chriſtians*, could induce us to believe that Diodorus Siculus had exaggerated the barbarity of *Heathen* policy! But there is much to be done, much, I fear, to be ſuffered, by all the ſtates of *Chriſtendom*, before the Goſpel of Chriſt can be ſaid to be eſtabliſhed amongſt them as a rule of life influencing their conduct.

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[*] Philoſ. Tranſ.

[†] Account of Mines, p. 20.

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* De Re Metal.

‡ Philoſ. Tranſ. 1777. p. 414.

§ Lib. III.

It is related of *Hannibal*, that he opened himſelf a paſſage through the Alps, by applying fire and vinegar to the Rocks which oppoſed his route. This mode of ſplitting rocks was, probably, not invented by Hannibal; he might have had frequent opportunities of obſerving a ſimilar practice in the ſilver mines in Spain, which daily afforded him three hundred pounds weight of ſilver [*]. There is nothing, indeed, ſaid of vinegar in the deſcription of the Egyptian mines before mentioned; but Pliny expreſſly affirms, that it was the quality of vinegar, when poured upon rocks, to ſplit ſuch as an antecedent fire had not ſplit; and that it was the cuſtom of miners to burſt the rocks they met with, by fire and vinegar [†]. This account of Hannibal's uſing vinegar in ſplitting the rocks, is generally looked upon as fabulous: for my part, I can eaſily conceive, that a few barrels of vinegar might have been of great uſe, if the rocks were of the limeſtone kind; and, whether they were ſo or not, I leave to be ſettled by thoſe, who have viſited the place where this famous attempt was made. Vinegar corrodes all ſorts of limeſtone and marble rocks; and hence, being introduced into the cracks made by the fire, it might be very efficacious in widening them, and rendering the ſeparation of large lumps by iron crows and wedges more eaſy. It is erroneouſly ſuppoſed, that a large quantity of vinegar was requiſite, for the vinegar did not reduce the whole maſs of rocks into a pulp; ſince Livy clearly informs us, that after the action of both the fire and vinegar, they were obliged to open their paſſage by *iron* inſtruments, which would have been wholly unneceſſary, had the main body of the rocks been diſſolved by the vinegar *.

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[*] Mirum adhuc per Hiſpanias ab Hannibale inchoatos puteos durare, ſua ab inventoribus nomina habentes. Ex queis *Bebulo* appellatur hodieque, qui CCC pondo Hannibali ſubminiſtrabat indies! Plin. Hiſt. Nat. L. 33. S. 31.

[†] Saxa rumpit infuſum (acetum) quæ non ruperit ignis antecedens. Plin. Nat. Hiſt. L. 23. S. 27. & L. 33. S. 21. where by *Silices* cannot be underſtood what we call flints, ſince vinegar has no action on flints.

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* — ardentiaque ſaxa infuſo aceto putrefaciunt. Ita torridam incendio rupem *ferro* pandunt. Liv. Hiſt. l. xxi. c. xxxvii.

END OF VOL. I.

G.P. III
BR. MUS.